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# WASTE OIL RECOVERY PRACTICES STATE OF THE ART, 1972

Environmental Quality Systems, Incorporated

Prepared for:

Environmental Protection Agency

December 1972

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# WASTE OIL RECOVERY PRACTICES
# STATE OF THE ART
# (1972)

Prepared For

STATE OF MARYLAND
MARYLAND ENVIRONMENTAL SERVICE

and

U.S. ENVIRONMENTAL PROTECTION AGENCY

By

ENVIRONMENTAL QUALITY SYSTEMS, INC.
Washington, D.C.

December, 1972

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# ABSTRACT

A study of waste oil production, collection, reprocessing, re-refining and disposal was carried out emphasizing the State of Maryland. State and national data on the origin and amounts of waste automotive, industrial and other waste oils is presented. The effect of changing gasoline lead concentration on waste crankcase oils is discussed and found to be significant with respect to future uses of such waste oils. The precise fate of waste oils within the State of Maryland is unknown but is being investigated. Methods for purifying, re-refining, reprocessing or disposing of waste oils of several types are presented. The predominant process for re-refining waste crankcase oils is the "acid/clay" method using sulfuric acid and adsorbent clays; the method produces large amounts of process wastes. Many methods have been investigated for waste processing. Newer processes reducing or eliminating the need for acids or clay are being introduced. Burning of waste oils for heat recovery or incineration is practiced; however, metallic compounds in the oil may present a health hazard if discharged to the atmosphere. The economics of waste oil reprocessing generally are not favorable because of high collection costs, low process yields, small plant operations and unfavorable legislation.

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# SECTION I

# INTRODUCTION

The Maryland Environmental Service, an office of the State of Maryland, has commissioned Environmental Quality Systems, Inc. of Washington, D.C. to carry out a review of the state-of-the-art of waste automotive and industrial oil technology. The work was partially funded by a grant authorized by the Environmental Protection Agency. This report describes current and projected waste oil volumes both within the State of Maryland and on a national basis. Current collection, re-refining and disposal techniques are discussed along with technology which has potential for application to reprocessing of waste oils. In addition, economic and legal factors which may affect the development of waste oil recovery programs on a statewide and nationwide basis, together with changes in automotive pollution control technology are discussed. In preparation of this report, over 200 references were consulted or reviewed, and discussions were held with waste oil reprocessors to gather technical information and cost data. Additionally, industrial and commercial sources of waste oils were interviewed either by telephone or personally. Several dozen foreign and U.S. patents were reviewed and reported on as was appropriate. A large number of re-refining process diagrams have been included together with descriptions of commercial, experimental, patented and allied petrochemical processes.

## SECTION II

## SUMMARY

A total of 28.4 million gallons of oil were sold in the State of Maryland in 1971. It is projected that about 31 million gallons per year will be sold by 1975. Sources of waste oil presently number over 6,100, the predominant number being gasoline stations and service and repair garages.

Nationally, a total of approximately 2.2 billion gallons of oils were sold during 1971 of which about one-half was for automotive use. Industrial oils are frequently reclaimed in-plant so that less than one-third of this category appears as waste. In contrast, about two-thirds of the total quantity of automotive lubricants become waste products after one use. The presence of metallic materials such as lead and many additives to the original product increase the difficulty of disposing of waste automotive lubricants.

A number of physical and chemical processes are available for reprocessing waste oils including gravity separation, centrifugation, filtration, distillation, solvent extraction, adsorption, thermal cracking, hydrotreating, dialysis and others. However, the major reprocessing techniques of commercial importance are settling and distillation combined with sulfuric acid and clay treatment. Simple settling and steam or vacuum stripping to remove light distillates is also practiced frequently. Direct disposal processes practiced frequently include road oiling to control dust, burning as a fuel, and incineration. Combustion methods are accompanied by air pollution in the case of waste crankcase oil, due to the high ash and lead content of these materials.

Various laws and regulations have been enacted to meet the problem of waste oil disposal. The State of Maryland's newly enacted regulations govern the transportation, handling and storage of waste oil materials. Existing excise tax and labelling legislation coupled with rising production costs due to the changing composition of motor oils and general inflationary tendencies have cut into the operating profits of re-refiners with the result that many have ceased operation.

Advances in re-refining technology and the focus of additional efforts on determining environmentally sound methods of disposal of waste oils are creating new options for the use of this valuable commodity.

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# SECTION III

## SOURCES AND AMOUNTS OF WASTE OILS IN THE STATE OF MARYLAND

Large amounts of waste oil materials are available for reprocessing or disposal from a variety of sources. The predominant sources for waste oils are tabulated in Table 1.

The total amounts of the various waste oils found in Maryland are not known exactly; however, an estimate of the amounts can be made from consideration of the total sales of lubricating and industrial oils and greases.

Although some edible oil and other plant and animal waste oils are produced in various industrial operations, much of this is collected and converted into soaps, animal feed additives and other useful products; thus, the residual waste materials are believed to be small in quantity. For this reason, edible oils are not included in the following discussion of waste oils.

According to the American Petroleum Institute (1), a total of 13,097,000 gallons of automotive lubricating oils, and 10,906,000 gallons of industrial lubricating oils, and a total of 3,242,000 gallons of other industrial oils were sold in the State of Maryland in 1969. In addition to the previous materials, a total of 5,835,000 lbs of various types of automotive and aviation greases and 7,151,000 lbs of industrial lubricating and other greases were sold in 1969. The total amount of lubricants sold in the State during 1969 was approximately 28.6 million gallons; of this amount, 27.2 million gallons fall into the category of lubricating oils and the balance is grease (assuming a density of 9 lbs/gal). Comparison with a previous census taken in 1967 indicates that a 6.2 percent annual growth in overall consumption of lubricants occurred during this period; however, the growth in various sectors is unequal as may be seen in Table 2 showing the tabulated and projected values for lube oils and grease sales in the State of Maryland over the period 1967 to 1975.

Further consideration of the data in Table 2 reveals that approximately 50 percent of all lubricant materials are sold for automotive use including lube oils and greases, while the balance of lubricant materials are used for essentially industrial purposes, based on the data from the year 1971. Using the graphical projection technique illustrated in Figure 1, it may be estimated that 51 percent of the total lubricant sold in 1975 will be for automotive use. In preceding years, this value was approximately 47 percent, indicating a small increase in the fraction of lubricants sold for automotive purposes.

Because of the value of many industrial lubricants and the economic incentives for reclamation of industrial oils, many plants recover their lubricants for further use. For industrial applications, an increase in the use of synthetic lubricants may be expected. For these reasons, a nominal decrease in industrial lube oils and greases is projected.

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## TABLE 1

## WASTE OIL SOURCES IN MARYLAND**

| Item No. | Type | No. of Sources | Waste Oil Type |
|---|---|---|---|
| 1 | Automotive service stations | 4,011 | used crankcase oil,waste hydraulic fluid, used transmission fluid |
| 2 | Automotive repair facilities | 402 | " |
| 3 | Automotive dealer repair facilities | 512 | " |
| 4 | Bus & truck service repair facilities | * | " |
| 5 | Bus and truck depot | * | " |
| 6 | Farm & construction equipment service & repair facilities | * | * |
| 7 | Aeromotive service hangars | 41 | waste fuels plus lubes and slops |
| 8 | Airline headquarters and major repair facilities | -0- | jet fuel, lubes and water |
| 9 | Marine service piers & marinas | 308 | * |
| 10 | Metalworking & machine shops | 502 | machine shop lubes & coolants |
| 11 | Railroad yards | * | diesel lubes, fuels, etc. |
| 12 | Industrial (commercial & institutional) rotary machinery lubes | * | turbine, spent gear, transmission, compressor & other lubes |
| 13 | Tank bottoms from petroleum storage facilities | 194 | oily sludges and slops |
| 14 | Port facilities, bilge & ballast pumpage | 10 | fuels, crude oil & slop oils |
| 15 | Food & textile industry wastes | 126 | waste animal & vegetable greases & oils and waste edible oils |
| 16 | Marine & industrial oil transfer spills | 10 | crude, heating, and other refined stocks |
| 17 | Chemical, petrochemical, and other processing & power industry | 56 | Waste ink oils, waste paints, waste petroleum products, waste detergent stocks, & deteriorated transformer oil |
|  | TOTAL ---- | 6,172 |  |

* Data not yet acquired
** Data does not include Washington, D.C.

## TABLE 2

## STATE OF MARYLAND

## LUBE OILS AND GREASE SALES: HISTORICAL AND PROJECTED

| TYPE | 1967 | 1969 | 1971 | 1975* |
|---|---|---|---|---|
| Automotive oil (gallons) | 12,195,000 | 13,097,000 | 14,057,000 | 16,000,000 |
| Aviation oils (gallons) | 89,000 | 66,000 | 64,000 | 44,000 |
| Industrial Lube Oils (gallons) | 8,478,000 | 10,906,000 | 7,708,000 | 6,600,000 |
| Other Industrial Oils (gallons) | 3,501,000 | 3,242,000 | 5,236,000 | 6,700,000 |
| Automotive & Aviation Greases (equivalent gallons based on 9 lbs per gallon) | 632,000 | 648,000 | 618,000 | 620,000 |
| Industrial Greases (equivalent gallons based on 9 lbs per gallon) | 882,000 | 800,000 | 733,000 | 600,000 |
| Total Volumes (gallons) | 25,777,000 | 28,759,000 | 28,416,000 | 30,600,000 |

---

* Note: The entries for 1975 are based on graphical projections from the data tabulated for the years 1967, 1969 and 1971. See Figure 1. Data due to the series "Sales of Lubricating Oils and Greases" by the U.S. Department of Commerce (Ref. 3).

(Additional Historical Data can be found in Table I-15, Appendix I.)

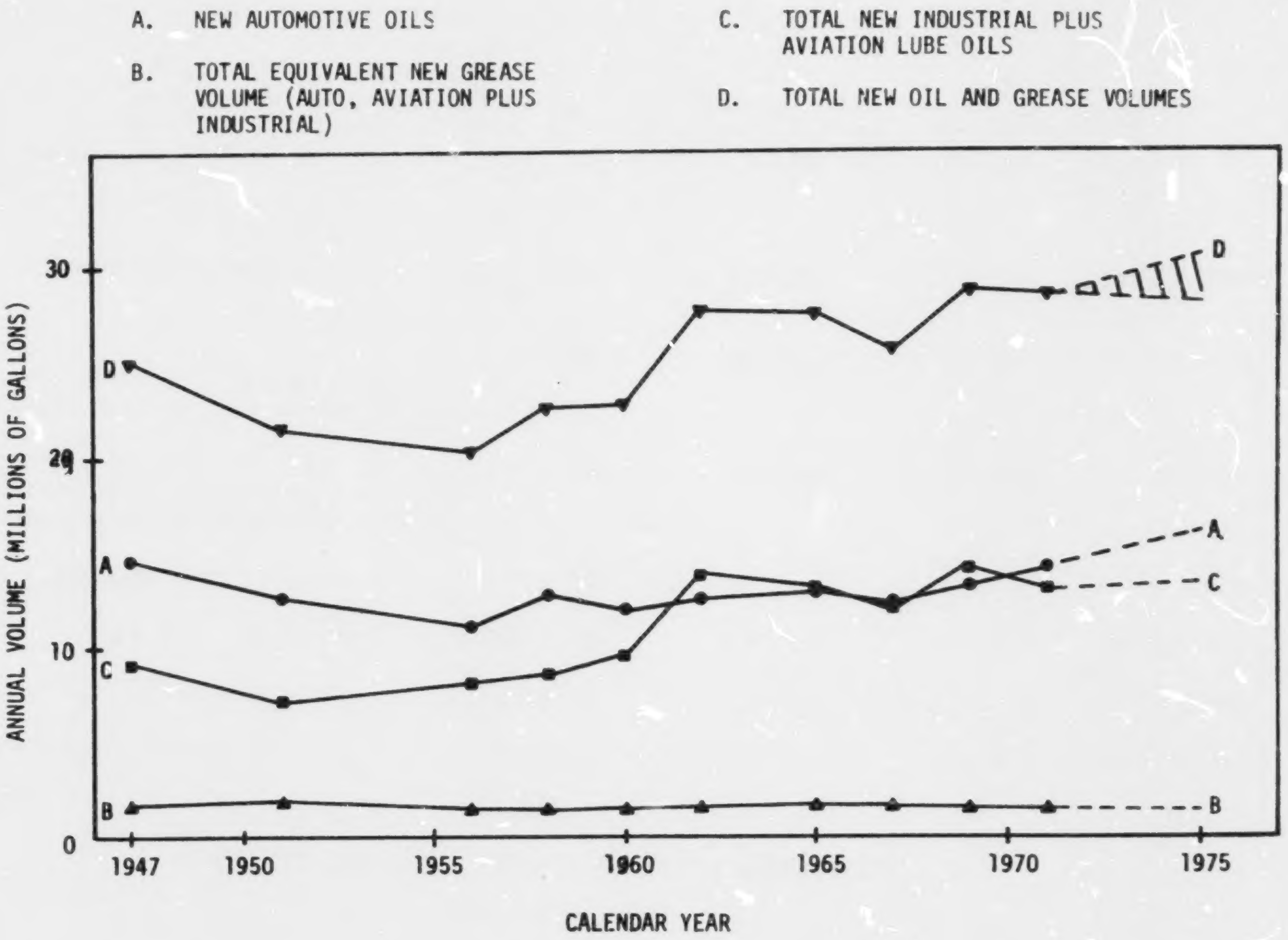

FIGURE 1-A. NEW OILS IN THE STATE OF MARYLAND
(Ref. 3, U.S. Dept. of Commerce)

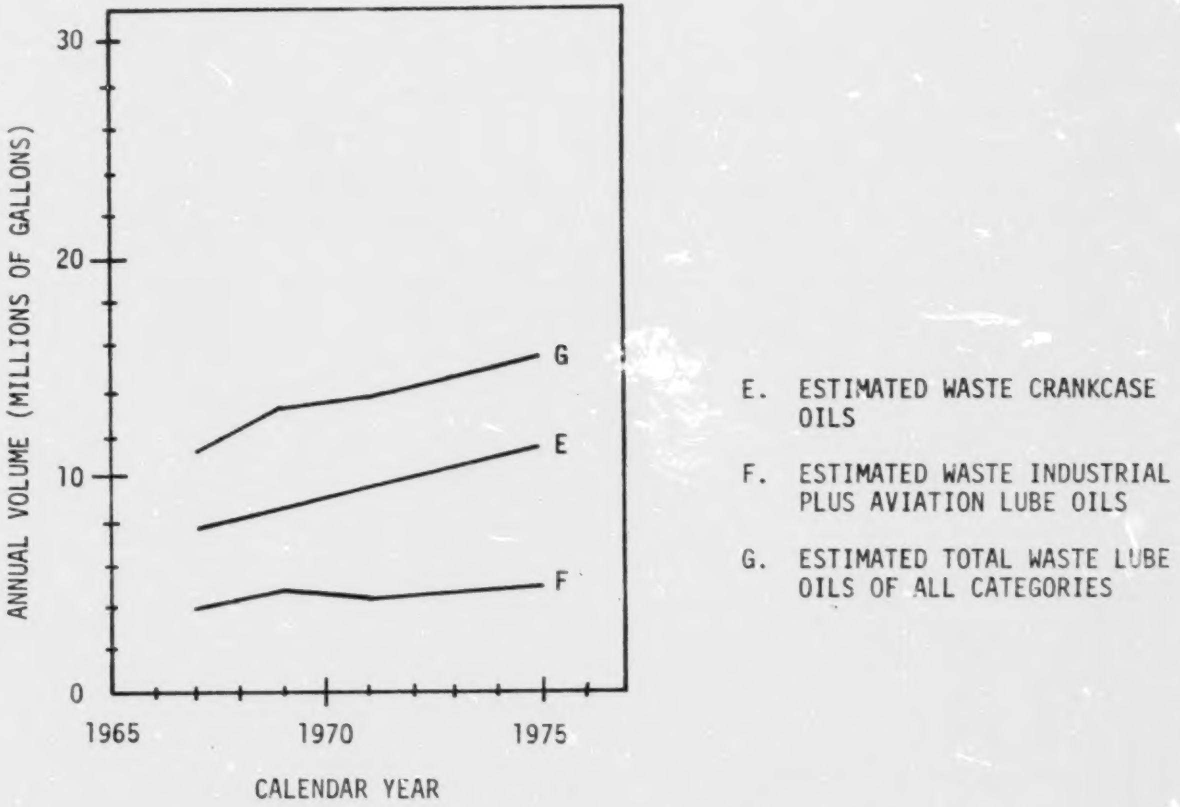

FIGURE 1-B. WASTE OILS IN THE STATE OF MARYLAND
(Ref. 3, U.S. Dept. of Commerce)

The residual amounts of waste oils shipped out of industrial establishments by waste oil scavengers have not been determined. An estimate of the amount of waste automotive oil produced in the State of Maryland in 1975 may be made by comparing the results obtained in the A. D. Little, Inc. study (2) in which approximately 66 percent of the new automotive oils resulted in waste oil requiring reprocessing or disposal. Using the same value of 66 percent, the waste automotive oil production for 1975 in Maryland would be approximately 10,600,000 gallons.

Using a similar projection technique, an initial estimate of the amount of waste industrial lubricants produced annually in the State of Maryland may be made. On a fractional basis it is estimated that the waste industrial oil produced is 29.6 percent of the amount sold (ref. 2, by computation). Applying this figure to the category consisting of industrial lube oils, other industrial oils, and industrial greases having a total projected volume of 13,900,000 gallons in 1975, the amount of industrial oily waste would approximate 4,100,000 gallons per year. Thus, the total annual waste oil production in Maryland projected for 1975 would be about 14,700,000 gallons based on the previous assumptions.

Although the forecasted waste oil production may vary somewhat from the actual amount because of the projection techniques employed here, it appears that the amount of waste oil to be disposed of will increase over the next 10 years and that effective recovery practices must be developed and used. The changes in the waste oil production based on the technical information from References 1,2 and 3 are shown in Figures 1-A and 1-B. The fate and ultimate disposition of these waste materials are described in succeeding sections of this report.

## SECTION IV

## NATIONAL WASTE OIL PROJECTIONS

On a national basis, it is estimated that over 2.3 billion gallons of virgin oil are used for industrial and automotive uses annually and that approximately 50 percent of this amount is consumed in the various applications of these materials (4). The balance of this material, 1.1 billion gallons is either available for recycling into various oil products or requires disposal. The amounts of various types of oils sold nationally are shown in Table 3. For the year of 1969, a net amount of 2.29 billion gallons of various lubricant materials were sold within the United States; this excludes sales to the Federal government and exports. On the basis of linear extrapolation using the period of 1967-1971 to determine the rate of change, the projected total national oil sales is 2.42 billion gallons in 1975. Exports have not been included because they do not contribute to waste oil nationally. The volume of Federal sales is about 1.5 percent of total sales but the amounts consumed within the U.S.A. have not been determined.

In 1969, the total number of registered vehicles in the U.S. was approximately 107 million units including buses, trucks and passenger vehicles. These vehicles required 88.1 billion gallons of motor fuel; the ratio of fuel to oil for passenger cars is cited as approximately 227 gallons of gasoline per gallon of oil for passenger cars (5). On an overall basis, taking all automotive lubricant oils and comparing them with the total number of vehicles of all types in the United States, the ratio of fuel to motor oil is approximately 81 gallons of fuel to one gallon of motor oil lubricant. In 1969, 1.051 billion gallons of motor oils were sold. Thus, approximately 10 gallons of lubricant oil were sold for each vehicle registered in the United States. The discrepancy between the ratios of 85 and 227 gallons of gasoline per gallon of oil previously cited is apparently due to the many stationary internal combustion engines, marine engines, and the many two- and four-cycle low horsepower portable engines currently in use in the United States.

It appears from inspection of the data in Table 3 that there is an increasing trend in the use of lubricants. On the basis that 66 percent of new automotive lube oil becomes waste automotive lube oil, the national amounts of waste lube oil would be approximately 680 million gallons in 1967, 690 million gallons in 1969 and a projected value of 730 million gallons in 1975.

Similar calculations may be made for the category comprising industrial lube oils and other industrial oils. As previously described, this category yielded 29.6 percent waste material. On this basis 300 million gallons of waste industrial oil would be produced in 1967, 330 million gallons in 1969, 330 million estimated for 1971 and 355 million gallons projected for 1975. A graphic presentation of the total growth in waste oil nationally is shown in Figures 2-A and 2-B. These composite curves are based on linear projections using the data reported for the period 1967 through 1971.

## TABLE 3

## NATIONAL OIL SALES

| Type | % Change* per year | Year (Million Gallons) 1967 | 1969 | 1971 | 1975** |
|---|---|---|---|---|---|
| Auto | + 0.9 | 1,032 | 1,051 | 1,071 | 1,107 |
| Aviation | - 9.9 | 13.1 | 9.9 | 8.4 | 5.9 |
| Industrial Lube Oil | + 1.17 | 699.1 | 781.2 | 726 | 751 |
| Other Industrial Oils | + 5.5 | 315.0 | 342.0 | 388 | 450 |
| Auto & Aviation Grease[a)] | - 1.7 | 52.4 | 53.2 | 49.8 | 47.3 |
| Industrial Grease[a)] | - 0.6 | 57.2 | 55.1 | 55.7 | 54.7 |
| TOTAL | + 1.49 | 2,168.8 | 2,291.4 | 2,298.9 | 2,415.9 |

---

* Based on 1967-71 sales (average % change per reporting period).

** Projected

a) Volume based on 9 lbs/gal. density

References: (1), (3)

(Additional Historical Data can be found in Table I-16, Appendix I.)

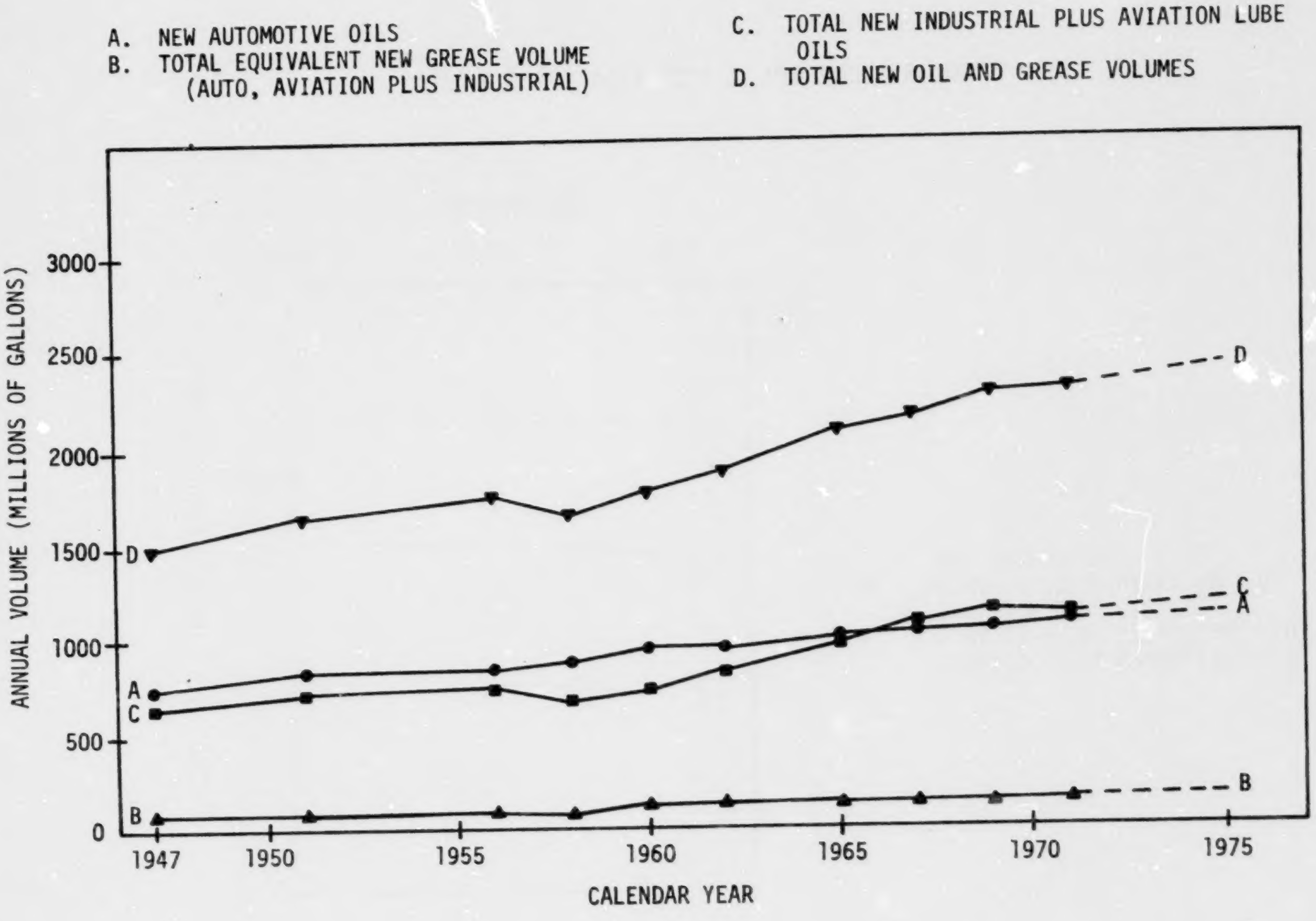

FIGURE 2-A, NEW OILS IN THE UNITED STATES

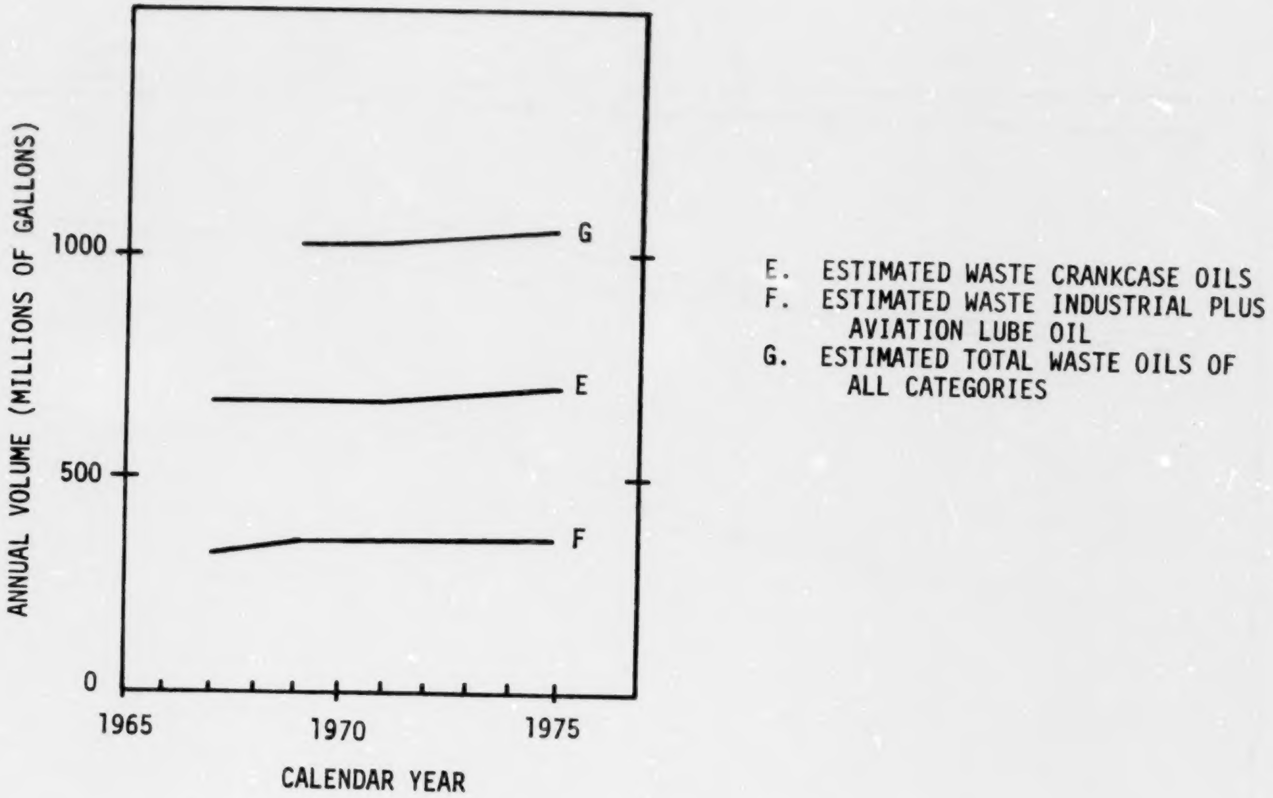

FIGURE **2-B**. WASTE OILS IN THE UNITED STATES

The difference between the total virgin oil sold and the total waste oil produced is the consumption by the machine itself (burning or leakage), discarding of oils in junked machinery and autos, and similar factors.

The per capita consumption, based on a population of approximately 200 million people in 1972, is about 11 gallons of all lubricants per person per year. Of this amount approximately 5 gallons is assignable to the automotive oil category.

The per capita oil consumption in the United States varies considerably from region to region. Additionally, large variances in the consumption of the two major categories, automotive and industrial oils, may be noted in Table 4-A. The exact causes for the variations in per capita oil consumption are not known but appear to be linked to regional characteristics such as degree of urbanization, level of agricultural activity and industrial output, coupled with the degree of development of public transportation. The regions or states having the highest proportion of per capita automotive oil consumption should generate a greater fraction of waste crankcase oil as compared with regions having higher per capita industrial oil consumption. Such consumption factors will affect the type of waste oils available for re-refining or other means of disposal. These variations are significant inasmuch as they affect the design of both the collection system and reprocessing system. Because of the greater spectrum of virgin oil products used industrially as compared with automotive uses, those regions having proportionately more industrial consumption will have more broadly varying waste oil types. In contrast, waste crankcase oils are found to be more uniform.

The decreasing consumption of engine oil as compared with fuel and the specific consumption of oil per mile travelled has been noted by several observers (5 & 7). Table 4-B shows the variation in oil consumption over the period 1950 to 1969.

Analyses of these data show that between the period 1950 to 1955 a decrease of 10-1/2 percent in oil consumption based on mileage was realized. In subsequent time periods, this decrease changes to 25 percent for the period 1955 to 1960; 30.5 percent for the period 1960 to 1965 and 28.5 percent for the period 1965 through 1969. Thus, the decrease in oil consumption seems to be levelling off as technological improvements become more difficult to achieve.

Lubricant materials shown in Tables 2-A and 2-B also include the category of automotive brake fluid. Statistics (5) show that approximately 10 million gallons per year of automotive brake fluid have been compounded and sold nationally over the period 1966 through 1969. A portion of this material is used in new applications while the balance is for replacement purposes. On the basis of an estimated 10 million new vehicles per year (5) and an assumed value of 0.1 gallon of hydraulic brake fluid per vehicle on the average, the balance yields an estimated amount of replacement brake fluid of 1 million gallons per year. This would be the maximum value of this category which might be recovered in a given year nationally providing adequate measures were taken to collect this material.

## TABLE 4A

## ANNUAL PER CAPITA OIL USE IN UNITED STATES (1971)

| STATE | OIL CONSUMPTION(GAL/PERSON/YEAR) | |
|---|---|---|
| | Automotive | Industrial |
| Alabama | 5.65 | 4.88 |
| Alaska | 7.05 | 2.15 |
| Arizona | 5.44 | 2.44 |
| Arkansas | 6.31 | 5.42 |
| California | 5.47 | 3.39 |
| Colorado | 5.65 | 2.94 |
| Connecticut | 3.37 | 4.07 |
| Delaware | 5.52 | 3.30 |
| District of Columbia | 3.25 | Unknown |
| Florida | 4.42 | 3.45 |
| Georgia | 5.57 | 5.52 |
| Hawaii | 3.66 | Unknown |
| Idaho | 7.30 | 1.86 |
| Illinois | 5.08 | 8.02 |
| Indiana | 5.17 | 8.45 |
| Iowa | 6.1 | 2.94 |
| Kansas | 10.0 | 4.62 |
| Kentucky | 7.02 | 7.10 |
| Louisiana | 6.31 | 11.20 |
| Maine | 5.10 | 2.8 |
| Maryland | 3.56 | 3.38 |
| Massachusetts | 3.57 | 3.64 |
| Michigan | 6.40 | 7.45 |
| Minnesota | 6.45 | 3.18 |
| Mississippi | 6.39 | 4.20 |
| Missouri | 6.91 | 3.35 |
| Montana | 9.15 | 2.45 |
| Nebraska | 9.50 | 3.91 |
| Nevada | 7.38 | 1.78 |
| New Hampshire | 3.45 | 1.18 |
| New Jersey | 3.82 | 8.70 |
| New Mexico | 7.10 | 5.15 |
| New York | 2.66 | 2.88 |
| North Carolina | 4.60 | 3.40 |
| North Dakota | 9.70 | 1.45 |

Table 4A continued

| STATE | OIL CONSUMPTION(GAL/PERSON/YEAR) | |
|---|---|---|
| | Automotive | Industrial |
| Ohio | 5.21 | 9.45 |
| Oklahoma | 7.28 | 5.61 |
| Oregon | 8.71 | 4.81 |
| Pennsylvania | 4.59 | 7.97 |
| Rhode Island | 3.06 | 2.75 |
| South Carolina | 4.09 | 2.38 |
| South Dakota | 9.79 | 1.01 |
| Tennessee | 5.38 | 4.79 |
| Texas | 6.39 | 9.89 |
| Utah | 6.65 | 3.39 |
| Vermont | 4.54 | 1.45 |
| Virginia | 4.14 | 2.57 |
| Washington | 4.91 | 2.82 |
| West Virginia | 5.32 | 13.50 |
| Wisconsin | 5.92 | 3.88 |
| Wyoming | 11.70 | 4.79 |

## TABLE 4B

## TRENDS IN MOTOR OIL CONSUMPTION

(Ref. 1, 7)

| YEAR | Gallons Oil per 100 Gallons Fuel | Quarts Oil per 1000 Miles |
|---|---|---|
| 1950 | 1.44 | 3.81 |
| 1955 | 1.25 | 3.42 |
| 1960 | 0.91 | 2.56 |
| 1965 | 0.64 | 1.78 |
| 1966 | 0.60 | 1.68 |
| 1967 | 0.54 | 1.52 |
| 1968 | 0.49 | 1.40 |
| 1969 | 0.44 | 1.27 |

A strict evaluation of the curves for automobile crankcase drainage coupled with the decrease in consumption per 1000 miles driven would seem to indicate that the quantities of oil that will be available in the years 1971 through 1975 will decline or at best stay at the levels noted for 1969 and 1970.

However, if the analyses are divided into several elements which include the impact of other factors, the long term trend in automotive oil sales will be a rise. During 1960, automobile sales increased and cars were being driven more miles per year. This would have shown an increase in the quantity of oil sold if the character of the oil had not been dramatically changed.

Whereas in the late 1950's oil was drained about every 2000 miles, oil in the late 1960's was drained between 4000 and 6000 miles. The automobile manufacturers have since reversed their trend for increased mileage between oil changes. They now suggest that oil be changed every 3000 to 4000 miles and filters every second oil change. It is felt that oil life has somewhat stabilized at this latter figure and that oil sales will parallel automobile sales quite closely.

Accordingly, two projections were made for auto lubes: one taking into consideration all the data and a second (more conservative) placing a much greater weight on oil sales during the previous three years. As the latter produces a higher value for crankcase drainage, it will be utilized to project the quantities of oils expected in the future.

The fact that the "grease" curve is flat in the face of greater auto and lube oil sales can be explained by the current and expanded use of non-lubricating fittings in rotating equipment.

## SECTION V

## PHYSICAL AND CHEMICAL CHARACTERISTICS OF WASTE OILS

The various sources described in the previous section may be classified into five broad types. These are: waste automotive lubricants, waste metalworking lubricants, waste heavy hydrocarbons (fuels and tars), waste animal and vegetable oils and fats, and waste industrial oil materials.

The first category - waste automotive lubricants - includes all crankcase oils, transmission fluid, differential gear lubricants, hydraulic oil, and small quantities of solvents frequently used in automotive installations.

Because of the blow-by in automotive engines, waste crankcase oils frequently have an appreciable portion of low boiling materials originating from gasoline. In addition, many of the constituents and additives in gasoline are transferred during engine operation to the crankcase; thus, lead is frequently found in concentrations of several thousand parts per million (ppm) in waste crankcase oil. In addition, water is found because of accidental introduction into waste and holding tanks and because of moisture formed during combustion in the automotive engine. Frequently, appreciable solid material and sediment accompany the waste oils. The contaminants in the waste automotive oil can be classified as volatile products, materials soluble in oil, and materials insoluble in oil. The volatile components generally are water and fuel. The soluble materials include many of the additives originally placed in the oil such as viscosity index improvers and detergent additives. The insoluble materials include sub-micron size carbon particles, inorganic materials such as atmospheric dust, metal particles, metal oxides and lead oxides originating during fuel combustion(8).

A typical analysis of waste oil is shown in Table 5 (9). In addition to the metals noted here, there are a large number of other trace metals present in used lubricating oils; a typical analysis of used lube oils showing the trace metal concentrations is shown in Table 6 (10). It is evident from the entries in the trace metal table that appreciable amounts of lead, barium, calcium and zinc are found in most used motor oils. Also, the exact amount reported on a given sample depends to some extent on the analytical method used, as is evident from the differences between values determined by emission spectroscopy and atomic absorption. Individual samples, and perhaps many types of waste oil, vary widely in metal content (led by an order of magnitude according to these data); this has important implications for waste oil processing. Additional properties of these samples are shown in Table 7. These values are important in assessing the degree of contamination of the used lubricant and in determining methods of processing to convert used oils into useful produces. Used automotive lubricating oils also contain appreciable amounts of gasoline introduced by means of blow-by as evidenced by the gasoline dilution test. They also contain relatively large amounts of sediment and water, and large amounts of ash. Much of the ash is due to additives originally blended with the oil; however, a large fraction originates from the fuel which contains lead and enters the oil by means of blow-by. These materials generally impair the use of spent

## TABLE 5

## TYPICAL WASTE AUTOMOTIVE OIL COMPOSITION
(REF. 9)

| Variable | Value |
|---|---|
| Gravity, °API | 24.6 |
| Viscosity @ 100 °F | 53.3 Centistokes |
| Viscosity @ 210 °F | 9.18 Centistokes |
| Flash Point | 215 °F (C.O.C. Flash) |
| Water, (By Distillation) | 4.4 Volume % |
| BS & W | 0.6 Volume % |
| Sulfur | 0.34 Weight % |
| Ash, Sulfated | 1.81 Weight % |
| Lead | 1.11 Weight % |
| Calcium | 0.17 Weight % |
| Zinc | 0.08 Weight % |
| Phosphorous | 0.09 Weight % |
| Barium | 568 ppm* |
| Iron | 356 ppm* |
| Vanadium | < 5 ppm* |

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* ppm = parts per million

TABLE 6
(Ref. 10)

## TRACE METALS FOUND IN USED AUTOMOTIVE LUBRICATING OIL

| Sample No. and Source | 1395 Gov't cars | 1396 Serve Your Self | 1397 Fina 40 | 1398 Texaco | 1399 Gulf | 1400 Phillips | 1401 Sinclair |
|---|---|---|---|---|---|---|---|
| **Metal** | Values in Parts Per Million | | | | | | |
| Aluminum | 30 | 20 | 10 | 20 | 10 | 10 | 10 |
| Copper | 10 | - | 20 | 10 | 120 | 5 | 5 |
| Iron | 510 | 200 | 260 | 160 | 150 | 800 | 450 |
| Lead | 1090 | 1740 | 1510 | 1820 | 960 | 2070 | 1480 |
| Silicon | 20 | 10 | 10 | 20 | 10 | 10 | 240 |
| Tin | - | - | - | - | 30 | 30 | - |
| Sodium* | 80 | 20 | 90 | 110 | 70 | 50 | 30 |
| Barium* | 540 | 170 | 100 | 145 | 900 | 20 | 10 |
| Calcium | 1900 | 1360 | 1770 | 2160 | 1170 | 1380 | 1490 |
| Calcium* | 1970 | 1430 | 1720 | 2010 | 1160 | 2690 | 2600 |
| Zinc | 1140 | 560 | 1340 | 1320 | 680 | 950 | 930 |
| Zinc* | 1360 | 780 | 1390 | 1610 | 990 | 1310 | 1220 |
| Magnesium | 80 | 20 | 270 | 260 | 150 | 110 | 20 |
| Magnesium* | 70 | 10 | 420 | 410 | 180 | 170 | 10 |

* By atomic absorption. All others by emission spectroscopy.

PRELIMINARY DATA
NOT TO BE REPRODUCED

## TABLE 7

## PROPERTIES OF USED AUTOMOTIVE LUBRICATING OILS
(Ref. 10)

| Property | SAMPLE NO.* 1395 | 1396 | 1397 | 1398 | 1399 | 1400 | 1401 |
|---|---|---|---|---|---|---|---|
| Specific Gravity | .910 | .918 | .909 | .906 | .896 | .965 | .916 |
| Viscosity @ 100 °F SUS | 352 | 412 | 424 | 413 | 262 | 753 | 433 |
| Carbon Res. Conradson | 5.1 | 6.0 | 5.3 | 5.2 | 3.8 | 12.6 | 7.8 |
| Flash Point °F | 182 | 230 | 280 | 200 | 230 | 250 | 180 |
| Ash (%) | 2.36 | 2.06 | 2.19 | 2.37 | 1.57 | 3.78 | 2.67 |
| Saponification Number | 11.3 | 19.6 | 17.1 | 15.4 | 12.7 | 35.4 | 18.0 |
| Gasoline Dilution D322-67, % | 7.2 | 1.1 | 0.6 | 1.0 | 0.8 | 0.9 | 2.0 |
| Bomb Sulfur Wt. % | .49 | .39 | .47 | .45 | .26 | .52 | .51 |
| Neutralization No. D974-64 | 4.26 | 6.31 | 5.49 | 5.21 | 4.00 | 14.26 | 7.15 |
| Pentane Insolubles % | 2.12 | 2.82 | 1.96 | 1.67 | 1.32 | 3.56 | 2.16 |
| Benzene Insolubles % | 1.92 | 2.35 | 1.84 | 1.48 | 1.17 | 3.33 | 1.98 |
| Coag. Pentane Insolubles % | 2.90 | 4.92 | 2.60 | 1.78 | 1.20 | 11.34 | 4.93 |
| Coag. Benzene Insolubles % | 2.43 | 3.64 | 1.96 | 1.45 | .99 | 7.90 | 4.08 |
| Antifreeze, (Glycol) | faint trace | neg | neg | trace (<300ppm) | neg | trace (<300ppm) | neg |
| BS&W, % | 6.0 | 5.0 | 6.0 | 5.5 | 3.2 | 9.3 | 9.2 |

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* See Table 6 for sources.

PRELIMINARY DATA
NOT TO BE REPRODUCED

lubricant either for further use as a lubricant or other applications until they are removed. Table 6 illustrates the large amount of metallic materials present in used crankcase oils. Although most compounded motor oils for modern internal combusion engines contain additives of metallo-organic nature, a large proportion of these metallic materials in used motor oils are introduced during use. Typically, the metals introduced by means of wear or combusion and corrosion are aluminum, copper, iron, lead, silicon and tin as tabulated, for example, in Table 6. Sodium, barium, calcium, zinc and magnesium frequently are added as compounds by the oil manufacturer to impart specific useful properties to the oil. As will be discussed in greater detail in other sections of this report, these metallic residues affect the ultimate treatment, use and disposition of waste crankcase oils.

Table 7 further describes the properties of used crankcase oils and illustrates the wide variations that may occur in the composition of used crankcase oils. For example, the gasoline dilution ranges from 0.8 percent to 7.2 percent; these values directly affect the fraction of rerefined oil available from the used oil. Similarly, the BS&W (Bottom Sediment and Water) affects subsequent reprocessing yields and methods.

It is interesting to note that the impurities found in used automotive lubricants are similar the world over. For example, Schilling reports French waste oils (7) to have a viscosity of 37 to 45 centistokes, bottom water and sediment of 2 to 8 percent, a water content ranging from 1 to 9 percent, and a gasoline dilution of up to 10 percent. Additional characteristics of used automotive lubricant oils have been reported (11,84); these data are shown in Tables 8A and 8B and 8C. It is apparent that wide variations in composition may occur thus affecting the value of the waste oil for subsequent applications and affecting the ability to process all materials equally well. Such variations make monitoring of the used oil quality a prerequisite to further handling.

Waste metalworking lubricants originate in the manufacture of various machinery articles. These include oil-based fluids, used without water, and emulsified aqueous fluids consisting of physical mixtures of oil and water plus certain additives. Metalworking lubricants may be classified (12) into three broad classifications; these are shown in Table 9.

Under use, these coolants and lubricants are subject to deterioration and degradation caused by bacteria, heat, metal particles, oxidation, introduction of contaminants from water used to make the so-called soluble coolants, and the introduction of tramp oil and grease. Thus, these metalworking lubricants and coolants must be replenished and replaced periodically to maintain their quality. In many cases, the metalworking fluids are recirculated, settled, filtered and subjected to other forms of purification enabling their reuse in the plant. Nevertheless, large quantities of these fluids must be disposed of. Both primary metal industries performing rolling and shaping of ferrous and non-ferrous

## TABLE 8A
(Ref. 84)

## PROPERTIES OF OVERHEAD DISTILLATES FROM AS-RECEIVED WASTE OILS

| Re-Refining Plant Location | Feed Density (gm/cc) | Engler Distillation* | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | INIT | 10% | 30% | 50% | 70% | 90% | BOTTS % |
| California | 0.8394 | 270 | 340 | 379 | 444 | 612 | | 35 |
| Michigan | 0.8491 | 276 | 344 | 482 | 600 | | | 55 |
| Mississippi | 0.8110 | 295 | 334 | 364 | 394 | 448 | 652 | 10 |
| Kansas | 0.8139 | 255<br>255 | 316 | 338 | 364 | 408 | 600 | 13 |
| Illinois | 0.8338 | 313 | 340 | 376 | 408 | 590 | | 30 |
| Minnesota | 0.8479 | 310 | 350 | 413 | 624 | | | 50 |

*NOTE: Atmospheric distillation showing initial (INIT) boiling point and subsequent boiling points in °F at various percent cumulative volume of distillate recovered from the original sample.

## TABLE 8B

## PHYSICAL CHARACTERISTICS OF USED AUTOMOTIVE LUBRICANTS
(Ref. 11)

| Source | Water (Vol. %) | Coagulated Pentane Insolubles (Wt. %) |
|---|---|---|
| **Service Station** | | |
| American Oil Co. | Nil | 4.00 |
| Gulf | Nil | 5.11 |
| Atlantic | 0.24 | 6.87 |
| Sunoco | Nil | 3.41 |
| Tidewater Flying A | Nil | 7.17 |
| Villanova Citgo Truck | 0.12 | 7.30 |
| **Collector's Tanker** | | |
| Waste Oil Collector's Sample Bridgeport, N. J. | 0.6 | 1.55 |
| **Typical Charge Stocks to Re-refining Plants** | | |
| Bridgeport, N. J. | 2.2 | 7.03 |
| Douglasville, Pa. | Nil | 6.40 |
| Newark, N. J. | 11.0 | 3.30 |

TABLE 8C
(Ref. 10)

## ADDITIONAL PROPERTIES OF USED CRANKCASE OILS

| Sample I.D. | Specific Gravity | Viscosity @100 F (SUS) | CCR* (% wt) | Flash Point (°F) | Ash (% wt) | Sap.No.** (mgKOH/gm) | Gasoline Dilution (Vol. %) |
|---|---|---|---|---|---|---|---|
| A | 0.910 | 352 | 5.1 | 182 | 2.36 | 11.3 | 7.2 |
| B | .918 | 412 | 6.0 | 230 | 2.06 | 19.6 | 1.1 |
| C | .909 | 424 | 5.3 | 280 | 2.19 | 17.1 | .6 |
| D | .906 | 413 | 5.2 | 200 | 2.37 | 15.4 | 1.0 |
| E | .896 | 262 | 3.8 | 230 | 1.57 | 12.7 | .8 |
| F | .965 | 753 | 12.6 | 250 | 3.78 | 35.4 | .9 |
| G | .916 | 433 | 7.8 | 180 | 2.67 | 18.0 | 2.0 |

* Conradson carbon residue

** Saponification number

## TABLE 9

## OIL-BASED METAL WORKING LUBRICANTS
(Ref. 12 )

I. OILS AND OIL BASE FLUIDS

  A. Mineral Oils - Uncompounded

  B. Fatty Oils

    1. Uncompounded
    2. Fatty Oils containing Chlorinated Compounds
    3. Fatty Oils containing Sulfurized Compounds
    4. Fatty Oils made by combining B-2 and B-3

  C. Mineral Oils - Compounded

    1. Mineral Oil/Fatty Oil Blends
    2. Sulfurized and/or Chlorinated Mineral Oil
    3. Mineral Oils containing Sulfurized Fatty Compounds and/or Sulfurized Non-Fatty Compounds
    4. Mineral Oils containing Chlorinated Fatty Compounds and/or Chlorinated Non-Fatty Compounds
    5. Mineral Oils containing Sulfo-Chlorinated Fats or Sulfo-Chlorinated Non-Fatty Compounds
    6. Mineral Oils made by combining C-3 and C-4
    7. Mineral Oils and/or Fatty Oils containing Nitrogen or Phosphorus Compounds or Solid Lubricants, etc. in addition to Compounds from the groups employed in C-1 through C-6

II. AQUEOUS EMULSIONS AND DISPERSIONS

  A. Oil in Water Emulsions (Soluble Oils)

    1. Mineral Oil - Emulsions of Class I-A
    2. Mineral Oil/Fatty Oil - Emulsions of Class I-B(1) or I-C (1)
    3. Heavy Duty or Extreme Pressure - Emulsions of Class I-C(2) Through I-C(7)

  B. Water in Oil Emulsions

    1. Mineral Oil - Emulsions of Class I-A
    2. Mineral Oil/Fatty Oil - Emulsions of Class I-B(1) or I-C(1)
    3. Heavy Duty or Extreme Pressure - Emulsions of Class I-C(2) through I-C(7)

  C. Colloidal Emulsions

    1. Regular - Emulsions of Class I-A
    2. Fatty - Emulsions of Class I-B(1) and I-C(1)
    3. Heavy Duty or Extreme Pressure - Emulsions of Class I-C(2) through I-C(7)

  D. Dispersions

    1. Physical Dispersions of Liquid (Class I) Materials

metals, and hardgood manufacturers such as automotive and appliance manufacturers, generate significant quantities of waste oils. Although their compositions are similar to those shown in the preceding Table 9, they are heavily contaminated with oxidized lubricant materials, sediment, and finely divided hard-to-filter particles. In general, used metal-working lubricants must be handled separately from other waste oils primarily because of their composition.

Heavy hydrocarbons and tars originating from tank bottoms, spills, tank cleaning, and port operations, can have compositions ranging from very light oils such as diesel oil, for example, up to heavy crude oil. In general, spills, when collected on water, produce materials which are very similar to the original composition providing they are not highly volatile; frequently, after collection, they can be separated by simple settling, the water drawn off, and the oily material may be used over again for its original purpose; however, volatile materials will evaporate and alter the composition of the original oil. The characteristics of several of these heavy hydrocarbon oils are shown in Tables 10 and 11. It appears from the data gathered by Hoxley (15) that the preponderant amount of spilled heavy hydrocarbons is crude oil which accounts for 80 percent of spilled heavy hydrocarbons; light oils and residual oils account for 18 percent and 2 percent, respectively. In addition to the fluid materials discussed above, oil contaminated solid or semi-solid materials are also produced during spills. The composition of some of these materials is shown in Table 12. It is evident from the values in the oil column of Table 12 that large amounts of recoverable oils are present and under suitable conditions could be separated from the solid impurities and put to use.

Waste plant and animal oils and fats originating from the food processing and edible oil manufacture generally are recovered as soap stocks, animal feed additives and similar uses. However, a small amount of these oils and fats fall into the category of oily waste materials not suitable for further processing but only for collection and ultimate disposal. Typically, these materials consist of fatty acids and glycerol esters of saturated and unsaturated fatty acids. Frequently the melting point of these materials is above room temperature and they may be discarded along with other "solid" wastes. Oily wastes from margarine manufacture and cooking operations using edible oils, have been reported to range from 60 to 80 percent oils and fats, the balance consisting of water, dirt, salt, milk solids, and other contaminants. The heating value of the oily fraction of this mixture is approximately 17,000 Btu per pound. It has been reported that these materials are easily pumped with the proper equipment (17).

The physical and chemical characteristics of a variety of other industrial wastes depend on the specific application and composition of the original lubricant or oil. Typically these wastes consist of spent turbine oil, spent transformer oil, mixtures of waste aviation jet fuel plus lubricants, waste gear box oils from industrial rotary machinery, waste heat transfer fluids, waste railroad lubricants, waste coke oven oils, and waste

## TABLE 10

## RECOVERED CRUDE PETROLEUM ANALYSIS
(Ref. 13)

| Fraction | Volume Per Cent | Sp. Gr. | °API |
|---|---|---|---|
| Light Gasoline | 2.0 | 0.701 | 70.3 |
| Total Gasoline and Naphtha (including Light Gasoline) | 15.8 | 0.766 | 53.3 |
| Kerosene Distillate | 12.1 | 0.811 | 43.1 |
| Gas Oil | 23.5 | 0.845 | 36.1 |
| Nonviscous Lubricating Distillate | 18.8 | 0.857-0.874 | 33.7-30.5 |
| Medium Lubricating Distillate | 9.6 | 0.874-0.885 | 30.5-28.4 |
| Viscous Lubricating Distillate | 1.4 | 0.885-0.886 | 28.4-28.1 |
| Residuum | 18.7 | 0.928 | 21.0 |

TABLE 11

## SOME PROPERTIES OF UNUSED PETROLEUM PRODUCTS

(Ref. 14 )

|  | Crude | High Gravity Naphtha | Low Gravity Naphtha | Jet Fuel | Kerosene | Gas Oil | White Oil | Motor Oil | Fuel Oil #1 | Fuel Oil #2 | Fuel Oil #4 | Fuel Oil #5 | Fuel Oil #6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gravity, °API | 13.5 to 33.5 | 45 to 75 | 30 to 53 | 40 to 55 | 40 to 46 | 30 to 33 | 29 to 32 | 24 to 30 | >35 | >26 | 9 to 36 | 6.5 to 24 | -3 to 23 |
| Sulfur | 0.3 to 4.0% may be sour | 0.02% | 0.02% | <0.10% | <0.13% | 0.2 to 2.0% |  | High | 0.1 to 0.5% | 0.2 to 1% | 0.2 to 2% | 0.2 to 4.8% | 0.3 to 5.25% |
| IBP* | 40°F | 95°F | 160°F | 100°F | 355°F | 400°F |  | ca. 640° | 360°F | 370°F | ca. 420°F |  | 492°F |
| EP* | >850°F | 206°F | 410°F | to 500°F | to 575°F | 800°F |  | 879° | 625°F | 675°F-90% | 683°F |  | 1262°F |
| Molecular Weight |  |  |  | 100-220 | 156-226 | 212-294 |  | 268 to 492 |  |  |  |  |  |
| Comments |  |  |  |  |  |  | Colorless (or nearly) Highly paraffinic | Phosphorus 1 part Sulfur 2 part Zinc 1/2 part (other additives) |  |  |  |  |  |
| Viscosity, 100°F (Centistokes) | 2.3-10.5 |  |  |  |  |  |  |  | 1.4-2.2 | <4.3 | 5.8-26.4 | 32.1 min. 81 max. | 92-638 |

*Distillation data: Initial Boiling Point (IBP)
End " (EP)

## TABLE 12

## COMPOSITION OF OIL-CONTAMINATED BEACH SAMPLES (PUERTO RICO)

(Ref. 16 )

| Sample No. | $H_2O$, wt-% | Oil, wt-% | Balance (Sand, etc.) wt-% |
|---|---|---|---|
| 1 | 0.4 | 43.9 | 55.7 |
| 2 | 2.2 | 1.4 | 96.4(1) |
| 3 | 8.8 | 48.0 | 43.2 |
| 4 | 40.4 | 13.2 | 46.4(1) |
| 5 | 29.8 | 60.9 | 9.3(1) |
| 6 | 77.4 | 8.5 | 14.1(1) |
| 7 | 28.2 | 54.7 | 17.1(1) |
| 8 | 10.3 | 7.3 | 82.4 |
| 9 | 20.4 | 13.4 | 66.2 |
| 10 | 40.8 | 5.0 | 54.2(1) |
| 11 | 16.3 | 6.8 | 76.9 |
| 12 | 11.0 | 12.5 | 76.5(1) |
| 13 | 25.9 | 8.1 | 66.0 |
| 14 | 17.7 | 2.7 | 79.6 |
| 15 | 14.4 | 6.8 | 78.8 |
| 16 | 14.4 | 6.8 | 78.8(1) |

---

(1) Seaweed present in sample.

petroleum processing oils. Depending on the volumes of these materials they may all be collected in a single tank truck and mixed. If the quantities are large enough, they may be collected separately and reprocessed for further use or disposed of.

Turbine oils have a long life and usually are inhibited to prevent oxidation, rusting and foaming. Although most turbine systems have on-line purification equipment of some type, impurities tend to build up necessitating flushing and changing of these lubricants. The fraction wasted is not known. Oil volume in the turbine system can range from 4,000 gallons for a 300 megawatt generator up to 18,000 gallons for a 1,000 megawatt generator (61). Thus, accidental contamination of a turbine oil system can result in a large amount of waste oil suddenly made available. Typically the viscosity of turbine oils range from 150 to 400 SSU at 100°F, although manufacturers do produce special products with viscosities around 900 SSU at 100°F. A typical turbine oil has a viscosity of 220 at 100°F, a viscosity index of 110, a flash point of 440°F, a pour point of 15°F and a neutralization number of 0.1, plus additives to control oxidation and foaming (18).

Transformer insulating oils similarly are purified to the degree necessary to maintain their insulating properties. Three measures of the performance of transformer oil currently are in wide use. These include dielectric tests, neutralization number, and interfacial tension. Dielectric tests (expressed in kilovolts) reveal the moisture content of the oil. The neutralization number (normally expressed as milligrams of potassium hydroxide per gram of oil sample) reveals the acid content and thus the degree of deterioration of the transformer oil. The interfacial tension (normally expressed as dynes per centimeter) reveals the amount of sludge in the oil. New oil normally has an interfacial tension of 45 dynes per centimeter and a neutralization number of less than 0.1 milligrams of KOH per gram. The dielectric strength normally is greater than 25 kilovolts (19). The interfacial tension normally is measured between the oil sample and a layer of distilled water. As the oil is subjected to the stresses, both thermal and electrical within the transformer, it deteriorates forming various acidic materials and accumulating moisture. Although these oils can be reclaimed, frequently their condition becomes poor enough to warrant disposal and replacement. Normally when the interfacial tension decreases to as low as 16 dynes per centimeter, corresponding to a neutralization number of about 0.8, a sludging condition has developed in the transformer and the oil must be reprocessed or disposed of. If the interfacial tension continues to drop and the neutralization number continues to rise, severe sludging may occur and it may be necessary to replace the transformer oil and dispose of the original charge. Some of the physical property control methods used for transformer oils appear suitable for other industrial oils as well.

It is estimated (20) that 10 to 15 percent of the installed transformer oil has to be replaced per year because of loss of quality. Occasionally deterioration is caused by transformer fires and similar catastrophic incidents. It has been reported that waste transformer oils are highly acidic and rich in organic peroxides making them unsuitable for further use without extensive re-refining.

A small amount of fireproof transformer oils such as commercial mixtures of tri-chlorobenzene and polychlorinated biphenyls enter into the waste category each year but because of the persistent nature and non-biodegradability of these materials, they are not normally discharged into the environment or wasted as such. Instead they are disposed of by controlled incineration in approved facilities. The density of this fireproof transformer oil is around 1.5 grams per cc.

Used gear oils usually are mixed with other plant oily wastes for ultimate disposal. These gear oils have SAE numbers ranging from 80 up to 250; frequently they contain sulfur-bearing or lead-bearing additives, antioxidants, and other additives. After use, these lubricants become contaminated with dirt, wear metal, water, and products of oxidation. These waste lubricating materials have properties similar to automotive crankcase lubricants and may be included with them for re-refining or other means of disposal.

The manufacture of coke for metallurgical and other purposes usually is attended by a formation of waste oils. These may be accumulated from tar and grease separators and by lagooning. These oils are combustible and may be used either as fuels or incinerated.

Oily wastes from petroleum refining operations can originate in various steps of the refining process including both physical and chemical processes. The total quantity of these waste materials usually recovered in API separators in a refinery may range from 0.1 to 2 percent of the total crude oil throughput (21). However, a value of somewhat less than 1/2 percent appears to be more frequent. Because of the large number of products produced in the petrochemical industry, the composition of recoverable slop oils from petroleum processing operations varies widely (22). Generally these recovered slop oils may be reused in some of the processing operations or can be used as fuels, or incinerated (23).

Waste oily materials from re-refining of spent automotive and industrial lubricants contain many impurities. Typically these materials are the result of acid and clay treatment procedures, distillation and filtration operations. The waste oily sludges resulting from these operations have been reported (24) to have an API gravity of 1 to 2 degrees, a lead concentration of 1.9 percent, barium ranging from 500 to 1,000 ppm, zinc around 2000 ppm, a pH range of 4 to 8, approximately 50 percent water, and up to 20 percent dirt. The metallic content of this material was analyzed extensively by spectroscopy; the results of a typical run are shown in Table 13, which lists the metal content of the waste oily sludge remaining after re-refining of predominantly used crankcase oils. The high concentration of metal in this waste oil sludge indicates that this material must be treated further to accomplish the ultimate goal of safe disposal.

## TABLE 13

## METAL CONTENT OF WASTE OIL RE-REFINING OIL SLUDGE
(Ref. 24)

| Element | Concentration (ppm) |
|---|---|
| Zinc | 2100 |
| Cadmium | <9 |
| Arsenic | <45 |
| Boron | 18 |
| Phosphorous | 1700 |
| Iron | 2200 |
| Molybdenum | <18 |
| Manganese | 63 |
| Aluminum | 560 |
| Beryllium | <0.1 |
| Copper | 190 |
| Silver | <0.8 |
| Nickel | <8 |
| Cobalt | <0.8 |
| Lead | >19,000 |
| Chromium | 28 |
| Vanadium | <18 |
| Barium | 740 |
| Strontium | 2.7 |

# SECTION VI

## PRESENT OIL CHARACTERISTICS VERSUS FUTURE OIL CHARACTERISTICS

The future composition of automotive engine lubricants can be expected to change. The primary influence in this case will be the reduction of lead content in gasoline (25). It is anticipated that by July of 1974 at least one grade of regular lead-free gasoline containing less than .07 gram of lead per gallon will be available for all of the general motoring public. Since lead is an important contaminant found in used automotive lubricating oils, its removal from gasolines will result in a marked decrease in lead concentration in used crankcase oils (26). One of the major effects of the elimination of lead from crankcase oils is the considerable reduction in air pollution control necessary for incinerating or combusting waste crankcase oils. The removal of lead will make combustion for heat recovery or incineration a more attractive disposal alternative.

However, lead removal from gasoline may have other effects. For example, recent tests by Lowther on the effect of removal of lead from gasoline show that the unleaded fuels may cause more varnish and sludge formation in engines (27). An example of this difference is shown in Figure 3, illustrating the sludge and varnish ratings using the standardized V-B test on a Ford engine. These ratings measure the performance of motor oils under specific conditions; formation of varnish and sludge on running surfaces results in increased contamination of the crankcase oil. These tests show that leaded fuels produced superior results with both the SE and SD type lubricants; the SE lubricant is the most recent API engine service classification for 1972 warranty approved lubricants. Chemical and Engineering News (28) suggests that a low-lead gasoline containing 0.5 gram of lead per gallon having an octane rating of 92 could be made available for those cars requiring this octane rating; this would include about 40 percent of existing cars; the balance of the cars requiring a higher octane gasoline (up to say 100) would be compounded with 4 grams of lead per gallon. In another report (29) the point that approximately six percent more fuel will be consumed when lead is eliminated as an additive from gasoline is brought out by Chemical & Engineering News. Thus, it may be anticipated that the amount of gasoline burned per unit of motor oil will tend to increase slightly thereby changing the characteristics of the waste crankcase oil due to greater exposure to products of combustion. The exact nature of the changes in waste crankcase motor oil composition is unknown at this time since only a small amount of unleaded gasoline has appeared on the market at this point. Future changes undoubtedly will result in waste oil composition changes, but the exact values these will take are currently unknown.

The heavy metal content of motor oils makes it unacceptable as a feed stock for catalytic petrochemical processing since these materials affect the performance of the catalyst. Thus, primary producers are reluctant to accept waste crankcase oil as part of their feedstock. Since most of the crankcase oil is available in high density areas where air pollution can be considered most critical, it appears that an acceptable alternative to

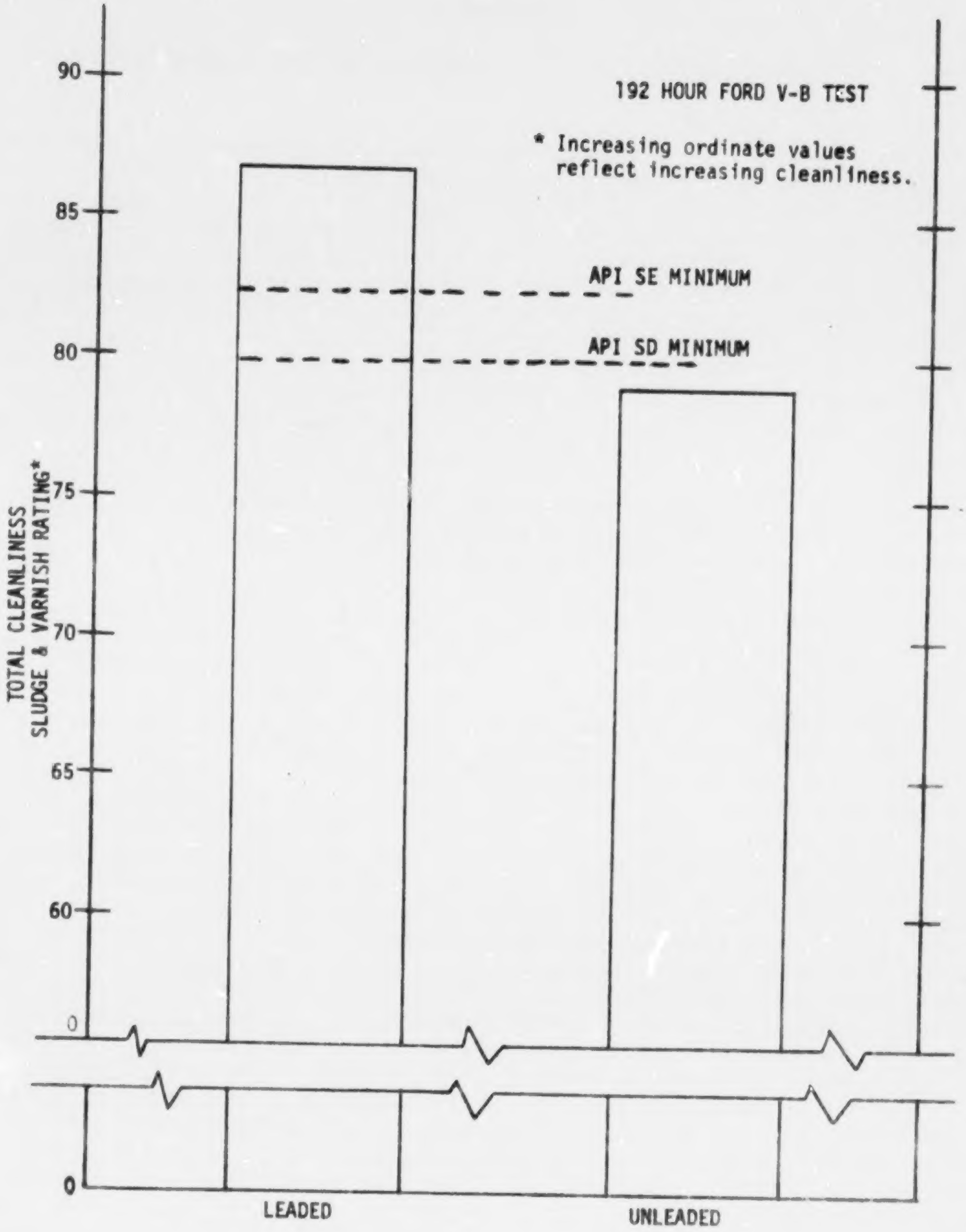

FIGURE 3 . EFFECT OF LEAD ON ENGINE CLEANLINESS reprocessing, providing the lead concentration and possibly other metallic materials and phosphorus of the crankcase oil are reduced, is to use crankcase oil as a fuel. This can be performed by mixing it with other fuelstocks in suitable proportions. The problem of atmospheric pollution by lead would disappear if it were severely reduced or eliminated from gasolines and subsequently from crankcase oils. The diverse forces including market factors and the conflicting interests of lead anti-knock producers, petroleum processors, the automotive manufacturers, and design and development engineering companies, suggests that the phase-out of lead in gasoline will be gradual and probably occur somewhat later than is anticipated currently.

Another part of the overall problem concerns the rate of scrapping of passenger cars and the removal of older vehicles from the road. The Automobile Manufacturer's Association estimates that the scrap rate(5) for passenger cars in 1968 was about six million vehicles. At that time there were approximately 78 million passenger vehicles on the road. If it is assumed that all new vehicles sold from 1971 onward can burn a low-lead gasoline and that a linearly increasing automobile population may be projected, it is possible to compute the percent of post-1971 vehicles on the road as a function of calendar year. This has been done in Figure 4 in which the effect of passenger vehicle age on crankcase oil composition may be noted. For example, in 1975 approximately, only 50 percent of the passenger vehicles will be capable of utilizing low-lead fuels; therefore, the crankcase oil composition on a macroscopic basis will be approximately 50 percent lower in lead than today's crankcase oils since only half the automobiles on the road at that time will be burning low-lead gasoline, while the other half are presumed to be operating on the high-lead fuels. Using this projective method, it may be estimated that in the year 1982 all vehicles on the road will be able to utilize low-lead or no-lead fuels; therefore, the waste crankcase oil from these vehicles will at that time be free of lead. The preceding projection does not account for any possible retrofitting of engines to permit them to burn low or non-leaded fuels or the development of new fuels compatible with old engines.

It appears, therefore, that the selection of any process or system postulated on contending with lead-bearing waste crankcase oil or otherwise avoiding the interfering effects of lead must be viewed as short range plans. On the other hand, the removal of lead from the crankcase oils should improve the range of applications of waste crankcase oils and the options for their utilization.

The preceding discussion has dealt exclusively with crankcase oil wastes which account for about 50% of the total waste lubricating oils. The balance of waste oils is composed primarily of industrial oils.

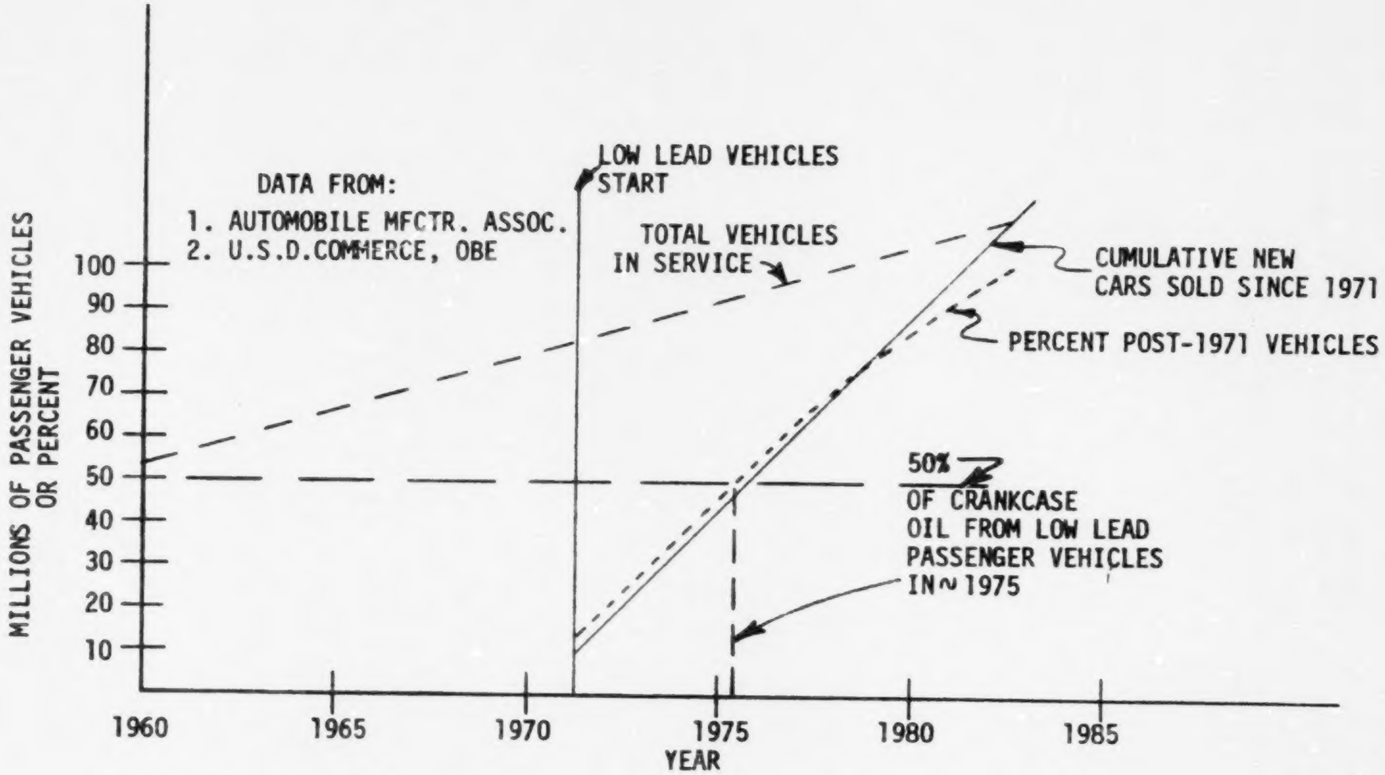

FIGURE 4. EFFECT OF PASSENGER VEHICLE AGE ON WASTE CRANKCASE OIL.

Since the characteristics of industrial oils are not expected to change greatly, the impact of industrial oil characteristics on waste oil recovery plans is not expected to be significant, although the amounts of oil available should increase. Some minor increases in the amount of so-called synthetic oils may be expected; however, the manufacturing costs of these oils are considerably higher than straight hydrocarbons, thus discouraging more extensive use except in special applications such as in aviation turbo-jet lubes. Further increases in spill materials, tank bottoms and ballast oil wastes are anticipated in proportion to the increase in fuel handling and consumption.

## SECTION VII

## PROPERTIES OF RECOVERED PRODUCTS

Because of the similarity of waste oils to the original raw materials, the composition of products recovered from waste oils is very similar to products which may be made from virgin raw materials. The number of products into which waste oils may be refined is very large, including the entire spectrum of products produced from virgin raw materials. Before describing the properties of recovered products, it is useful to examine the properties and specifications of virgin products.

Oils for automotive engine and diesel engine service have been classified by the American Petroleum Institute and identified with a code letter; Tables I-1 and I-2 of the Appendix list the various classifications of motor oils (31,32) and their general range of applications. These oils are further specified in a group of military specifications including Mil-L-46152 and Mil-L-2104C shown in Tables I-3 and I-4, respectively, in the same Appendix. The properties of several virgin oil products are shown in Table 14 for reference. In addition to the specifications and classifications shown in these tables, there are a large number of acceptance tests used to evaluate lubricating oils. Many of these tests have been developed under the American Society of Testing and Materials (ASTM) together with the American Petroleum Institute and other organizations. The ASTM established a series of Test Sequences. These ASTM Section G-IV tests were designed to measure such factors as low temperature and medium speed scuffing and wear, low temperature and deposits and rusting, high temperature oxidation, high temperature, high speed tappet scuffing and wear, insolubles, sludge and screen clogging. In addition to these factors, many motor oils are evaluated by individual automotive manufacturers. For example, Ford Motor Company has required special acid neutralizing tests, special rust and corrosion bench and engine tests, special 289 cubic inch engine sludging tests, and other similar tests. The Chrysler Corporation requires, for certain services, an anti-scuff test procedure, special viscosity measurements using the Ferranti-Shirley Viscometer and special humidity tests. General Motors in its Buick Division has a rocker arm shaft-wear test and special short trip service tests ("Aunt Minnie" tests); their Cadillac Division has a special 40-hour engine test. The complexity of some of these tests may be seen from some of the factors considered in the methods of operation used as shown in Tables I-5, I-6, I-7 and I-8 of Appendix I. These performance tests provide the ultimate assessment of the functionality of a specific lubricant, since the API or SAE oil classification does not necessarily guarantee specific performance by that lubricant. For example, in a series of tests reported by Booth (33) shown in Table 15, there was a wide variation in the physical properties of different oils bearing the same SAE or API classification. These variations were large enough to affect engine performance. It appears, therefore, that a combination of the API and SAE classifications together with appropriate bench and engine tests are required to describe any specific automotive engine lubricant.

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## TABLE 14

### SOME PROPERTIES OF VIRGIN CRANKCASE OILS
(Ref. 31)

| Sample No. | Oil Type | Specific Gravity | Viscosity @ 100°F (SUS) | CCR* (%) | Flash Point (°F) | Ash (% wt) | Sap. No. ** (mgKOH/gm) |
|---|---|---|---|---|---|---|---|
| 1 | SAE 30 | .890 | 540 | 1.5 | 415 | 1.17 | 3.53 |
| 2 | SAE 30 | .892 | 565 | .5 | 400 | .39 | 1.61 |
| 3 | SAE 30 | .888 | 517 | 1.0 | 415 | .64 | 2.73 |
| 4 | 10W-30 | .877 | 334 | 1.1 | 385 | .98 | 2.87 |
| 5 | 10W-30 | .882 | 441 | 1.8 | 330 | 1.23 | 4.08 |
| 6 | SAE 40 HD | .900 | 946 | 1.1 | 385 | .66 | 2.01 |
| 7 | SAE 30 HD | .890 | 522 | .1 | 380 | .77 | 5.44 |
| 8 | 10W-30 | .871 | 351 | .5 | 360 | .35 | 2.13 |

* Conradson carbon residue

** Saponification number

## TABLE 15

## PHYSICAL PROPERTIES OF SECOND AND THIRD LINE MOTOR OILS

(Ref. 33)

| Sample No. | SAE Grade | API Service | Viscosity (SSU) 100°F | Viscosity (SSU) 210°F | V.I.** | Pour Point (°F) | Comments |
|---|---|---|---|---|---|---|---|
| 1 | 20 | ML | 257.1 | 46.3 | 42 | -10 | Non Additive |
| 2 | 30 | ML | 402.3 | 58.0 | 96 | +10 | Non Additive |
| 3 | 30 | ML | 523.0 | 53.4* | 7 | 0 | Non Additive |
| 4 | 20 | ML-MM | 396.3 | 58.1* | 99 | +5 | Light Treat |
| 5 | 20 | ML-MM | 376 | 56.6 | 97 | -10 | Light Treat |
| 6 | 20 | ML | 466 | 63.3* | 104 | +30 | Non Additive |
| 7 | 20 | ML-MM | 322.5 | 53.7 | 98 | 0 | Non Additive |

* Does not meet SAE Crankcase Oil Classification

** Viscosity Index

Re-refined products may be reused directly after purification, or they may be blended with other products to produce a product suitable for its original intended use, or the re-refined products may be used in other service categories. For example, in Table 16 a diesel lube oil suitable for reuse was produced by a relatively simple process. This particular example of a re-refined product is a straight mineral oil without any additives.

Earlier piston aircraft engines (around 1950) used re-refined engine oils. Table 17 illustrates the properties of some of these re-refined oils as compared with the used and new oils. Comparison of the values in this table show that re-refined oils have characteristics similar to the new oils.

The characteristics of regenerated oil described by Bonnifay and Dutriay (37) recovered from spent crankcase oil are described in Table 18. When compared with the properties of oils in Table 14 it is apparent that the properties deviate significantly from virgin oil products. The low ash indicates absence of sufficient additives. However, it may be that this material could possibly be blended with other stocks to produce a straight or additive-type lubricant having suitable characteristics.

Properties of products recovered from another process (38) are shown in Table 19. This particular process used by the National Oil Recovery Corp. does not use clay but rather steam distillation and vacuum flash distillation to produce a range of products from low boiling naphthas to very high boiling bottoms products. Comparison of this table with the properties of unused petroleum products as shown in Table 11 shows that a range of useful products may be produced from used crankcase oils.

The analysis of a group of re-refined oils (39) are shown in Table 20 on work performed by the U.S. Bureau of Mines. Metallic additives also were determined in the Bureau of Mines work as shown in Table 21 which also shows the composition of two samples of virgin products. Note that, due to relatively high additive concentrations, the virgin products are high in metal content. It appears, from the analyses shown contrasting samples 1407 and 1410 with the other samples in the table, that re-refining has removed much of the additives originally compounded with the oils.

In a re-refining process evaluated at Villanova University (11), various purified oil fractions (See Table 22) which may be useful for blending into lubricating stocks and similar uses have been produced. Such applications represent useful outlets for recovered products. In this same work, it is reported that blending pretreated crankcase oils in which water and sediment had been removed with a fuel blending stock produced a number 4 heating oil. Use as a constituent clear fuel in this case constituted an important option for ultimate disposal of recovered products. Various samples were prepared using a virgin fuel oil blending stock ranging from 23 to 28.5 percent to produce viscosities of the finished blend ranging from 98.4 to 100.6 SSU at 100°F.

## TABLE 16

## REPRESENTATIVE R.R. DIESEL LUBE OIL BEFORE AND AFTER REFINING (STEAM STRIPPING)*

(Ref. 36)

| Lot No. | SUS VISCOSITY AT 100°F. | | Flash °F | |
|---|---|---|---|---|
| | Before | After | Before | After |
| 1 | 966 | 1041 | 410 | 450 |
| 2 | 959 | 1110 | 425 | 450 |
| 3 | 959 | 1068 | 410 | 445 |
| 4 | 720 | 1090 | 350 | 445 |
| 5 | 995 | 1043 | 440 | 435 |
| 6 | -- | 1002 | -- | 440 |
| | Average. | 1059 | | |
| Specification ..................... | | 1050 minimum | | 440 minimum |

* Treatment 0.66 lbs. clay/gal. 510°F.

## TABLE 17

## PROPERTIES OF RE-REFINED USED AIRCRAFT ENGINE OIL

(Ref. 36)

| | Used Oil (1 Eng.) | Test 1 Re-refined | New | Used Oil | Test 2 Re-refined | Test 3 Re-refined |
|---|---|---|---|---|---|---|
| Gravity A.P.I. | 25.4 | 27.0 | 27.1 | 25.2 | 27.0 | 26.9 |
| Vis. SUS 100 °F | -- | 1575 | 1555 | -- | 1617 | 1683 |
| Vis. SUS 210° F | 118.3 | 115.0 | 115.2 | 118.8 | 117.5 | 120.5 |
| V.I. (viscosity Index) | -- | 97 | 98 | -- | 97 | 97 |
| Flash° F | -- | 540 | 545 | -- | 540 | 545 |
| Acid No. | 0.25 | 0.03 | 0.03 | 0.25 | 0.03 | 0.03 |
| Dil. % | 1.6 | -- | -- | 1.4 | -- | -- |
| C. C. R. % * | -- | 0.6 | 0.6 | -- | 0.75 | 0.75 |
| Ash % | 0.52 | -- | Nil | 0.53 | -- | -- |
| Iodine No. | -- | 15.7 | 16.3 | -- | 15.4 | 16.6 |
| Aniline No. °C | -- | 121.1 | 121.1 | -- | 121.1 | 122.2 |
| Color ASTM | -- | 6 1/2 | 8 | -- | 8 | 8 |

* Conradson carbon residue

## TABLE 18

## PRODUCT CHARACTERISTICS* RECOVERED LUBE OIL

(Ref. 37)

| | |
|---|---|
| API° | 28.8 |
| SG (Specific gravity) | 0.883 |
| Viscosity, SSU at 100°F | 460. |
| 210°F | 60. |
| Viscosity Index | 99.5 |
| Conradson carbon wt% | 0.23 |
| Acid number | 0.05 |
| Ash, wt% | Trace |
| NPA color | +2 |
| Metal content (ppm): | |
| barium | 0.5 |
| calcium | 1 |
| phosphorus | 10 |
| lead | 1 |
| zinc | 0.5 |

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* Waste crankcase oil feedstock processed by propane extraction followed by acid/clay treatment.

## TABLE 19

## PHYSICAL PROPERTIES OF PRODUCTS RECOVERED FROM STEAM AND VACUUM DISTILLATION PROCESS

(Ref. 38)

| Cut | Name | Color (ASTM) | Viscosity Saybolt Seconds Univ. (SSU) | Boiling Range (°F) Init./Final | Specific Gravity (gm/cc) | Flash Pt. Open Cup (°F) |
|---|---|---|---|---|---|---|
| 1. | Naphtha | | | 145 - 446 | .797<br>46° API | |
| 2. | Barometric | 4 1/2 | 33-34@ 100°F | 400 - 680 | .860<br>33° API | |
| 3. | Light Sidestream | 8 | 100 @ 100°F<br>39.1 @ 210°F | 680 - 792 | .873<br>30.5° API | 350 |
| 4. | Heavy Sidestream | 8 | 222 @ 100°F<br>47.6 @ 210°F | 792 - 900 | .879<br>29.5° API | 430 |
| 5. | Bottoms | Dark | 284 (Furol) @ 122°F | 900 - up | .994<br>10.9° API | |
| | | | | | 1.0<br>10° API | |
| | | | | | Av. S.G. Feed Stock<br>.903<br>25.1° API | |

## POTENTIAL APPLICATIONS FOR ABOVE PRODUCTS

| Cut | Application |
|---|---|
| 1,2 | Solvent, thinner, diesel fuel or light fuel oil blend |
| 3,4 | Blend with virgin products for use as lubricants, diesel fuel, paint vehicles, plasticizers |
| 5 | Roofing compound |

## TABLE 20

## INSPECTION TESTS OF SIX RE-REFINED OILS
(Ref. 39)

| Oil Number | Saponification Number D-94-62 Average | Acid Number D974-64 Average | Gasoline Dilution D322-67 Average | Insolubles D893-69 Pentane | Insolubles D893-69 Benzene | Antifreeze Contamination |
|---|---|---|---|---|---|---|
| 1414 | 0.29 | 0.13 | 2.3% | 0.03% | 0.04% | Negative |
| 1415 | 0.35 | 0.15 | 0.36 | 0.03 | 0.03 | Negative |
| 1416 | 0.15 | 0.05 | 0.0 | 0.02 | 0.05 | Negative |
| 1417 | 0.23 | 0.08 | 0.32 | 0.01 | 0.02 | Negative |
| 1418 | 0.46 | 0.13 | 0.0 | 0.02 | 0.02 | Negative |
| 1419 | 0.23 | 0.08 | 0.40 | 0.04 | 0.04 | Negative |
| 1407* | 2.87 | -- | 0.0 | -- | - - | Negative |

* Virgin 10W -30 shown for comparison.

PRELIMINARY DATA
NOT TO BE REPRODUCED

# TABLE 21

# TRACE METALS IN RE-REFINED OILS (a)

(Ref 39)

| Sample No. | Sodium ppm | Barium ppm | Calcium ppm | Zinc ppm | Magnesium ppm |
|---|---|---|---|---|---|
| 1414 | 110 | <1.0 | 4.4 | 0 | 0 |
| 1415 | 97 | 1.2 | 24 | 0 | 1.0 |
| 1416 | 111 | 1.3 | 14 | 0 | <1.0 |
| 1417 | 107 | 1.5 | 3.0 | <1.0 | 0 |
| 1418 | 95 | <1.0 | 1.8 | 0 | 0 |
| 1419 | 106 | 1.6 | 3.2 | <1.0 | 0 |
| 1406 | 285 | 15 | 5 | 25 | 3 |
| 1412 | 285 | 20 | 15 | 35 | 5 |
| 1407* | 270 | 2840 | 1470 | 940 | 5 |
| 1410** | 490 | 50 | 970 | 1490 | 620 |

(a) By atomic absorption

* Virgin SAE 10W-30 shown for comparison

** Virgin SAE 30 shown for comparison

PRELIMINARY DATA
NOT TO BE REPRODUCED

## TABLE 22

## PRODUCTS RECOVERED BY VACUUM DISTILLATION OF PRETREATED CRANKCASE OIL FEED

(Ref. 11)

| Fraction No. | Density (gms/cc) | Viscosity at 100°F (SSU) | Viscosity at 210°F (SSU) | Viscosity Index | Color # (NPA) | Sulfated Residue % | Coagulated Pentane Insoluble % |
|---|---|---|---|---|---|---|---|
| 1 | .870 | 64.6 | 32.4 | - | 6 | - | .038 |
| 2 | .873 | 66.6 | 35.5 | - | 4.5 | - | .00 |
| 3 | .870 | 93.3 | 37.9 | - | 3.5 | - | .00 |
| 4 | .869 | 108 | 39.4 | - | 3.0 | - | .00 |
| 5 | .869 | 128 | 41.0 | 80 | 3.0 | .002 | .00 |
| 6 | .870 | 156 | 43.4 | 95 | 3.5 | - | .00 |
| 9 | .876 | 242 | 47.1 | 71 | 3.5 | .036 | .00 |
| 10 | .878 | 310 | 52.6 | 90 | 3.5 | - | .00 |
| 11 | .879 | 401 | 57.4 | 93 | 4.0 | .003 | .00 |
| 12 | .882 | 491 | 62.7 | 96 | 6.0 | .01 | .00 |
| Bottoms | .947 | - | - | - | black | 15.09 | 27.4 |

The specified viscosity range for number 4 fuel oil is 45 to 125 SSU at 100°F. Another application of specific fractions shown in Table 22 is compounding with sulfur or other active agents to produce cutting oils having a viscosity, say, in the range of 120 to 200 SSU at 100°F; such fractions could be blended with commercial sulfurized cutting oils as a mineral oil diluent as suggested by one manufacturer for his virgin oil products (40).

In U.S. Patent No. 2,822,320 a hydrazine-treated used lubricating oil was reported to have the properties shown in Table 23 (57). This patent illustrates a treatment method to produce a reusable oil; however, the patent does not describe any product verification by means of engine performance testing. The low ash content indicates the loss of much of the original additives thereby detracting from the potential value of the recovered product.

Kremer describes a process by which used crankcase oil having a neutralization number of 3.1 and a black color, is treated to produce a reclaimed oil having an acid neutralization number of 0.08 (50). The author claims that this reclaimed oil has improved oxidation and color stability and after addition of oxidation inhibitors and sludge dispersants, produces an oil equal to or better than unused virgin oil. Such claims, naturally, require substantiation by extensive product testing.

Many of the products discussed previously resulting from waste oil purification processes may be blended into products suitable for other applications. Typical examples of the properties of such commercial virgin products are shown in Tables I-9 through I-13 of Appendix I.

In addition to the previous recovered product applications described, recovered or pretreated crankcase and industrial waste oils may have a potential use in petrochemical processes similar to ones employing virgin raw materials. For example, these recovered products could be used as feed to a typical heavy oil cracking plant making ethylene, propylene, butylenes and similar olefinic materials. The composition of heavy oil feedstock is shown in Table I-14 of Appendix I and by comparison illustrates that products from waste oil processing could be used as feedstocks for olefin manufacture. Similar feedstock composition and physical characteristics are noted by Kitzen (44). It should be noted that such processes are adversely affected by metallic contaminants; consequently, any pretreatment of crankcase oils for application as an olefin feedstock would have to ensure adequate removal of metals.

The process of producing oil-derived proteins has been described (45) recently; feedstocks for these processes are reported to contain $C_{10}$ to $C_{18}$ alkanes which may be isolated from the oil fractions described in previous portions of this text. Such options for treating waste oils are valuable tools for ultimate disposal. The production of protein from industrial wastes is potentially an important use for waste oils and is the subject of a forthcoming study by the University of Cardiff, London, England (126). Such developments in allied process technology may yield benefits such as the production of new materials from waste oil sources.

## TABLE 23

## HYDRAZINE-TREATED USED CRANKCASE OIL

(Ref. 57)

| Variable | New Oil | Used Oil | Hydrazine-Treated Oil |
|---|---|---|---|
| Viscosity @ 100° F (SSU) | 519 | 666 | 423 |
| Viscosity @ 210° F (SSU) | 65 | - | 59.6 |
| Viscosity Index | 99 | - | 99 |
| Neutralization Number | 0.21 | 0.48 | 0.12 |
| Ramsbottom Carbon (%) | 0.24 | 6.98 | 0.32 |
| Ash (%) | 0.23 | 1.86 | 0.09 |
| NPA Color | 2-1/2 | - | >8 |
| API Gravity (°API) | 28.5 | - | 27.6 |
| Naphtha Insolubes | - | 7.39 | 0.03 |
| Pour Point (°F) | - | - | +5 |

# SECTION VIII

## TRENDS IN OIL USE

The ever-changing performance requirements for internal combustion engines, changes in internal combustion design, and increasing mechanical stresses calling for higher speeds and greater bearing loads and higher temperatures, have created the requirements for new lubricants. Additionally, other types of oil materials such as transformer oil and aviation oil with a much different chemical structure are now available in the so-called synthetic oil form. Many observers and writers (7, 46, 47, 48) on lubricating oils have documented this ever-changing scene. Thus, we can expect a continuing change both in the composition and application of industrial and automotive engine oils and, as a consequence, in the quality of used or waste lubricant oils. For example, recently introduced synthetic oils (46) have been applied as hydraulic fluids, liquid dielectrics, turbojet lubricants, instrument oils and many other uses. These materials include synthetic polymerized olefins, alkylated condensed ring aromatics, silicones, poly-alkylene glycols, diesters, fluorocarbons, and solid materials such as molybdenum disulfide, graphite, and boron nitride. The polyalkylene glycols have unique properties indicating their capability to remain free of deposits during operation in internal combustion engines. Esters of various monobasic acids and certain alcohols also have been found to have good properties as lubricating oils.

Additional factors which must be considered with respect to future oil uses are the introduction of new types of engines such as the Wankel engine for surface transportation, the possible introduction of sealed Rankine cycle engines such as the Lear "steam-mobile" and motor-driven storage-battery powered surface vehicles. To this we add the impact of the changing fuels picture caused both by shortages of petroleum on a world-wide basis as well as in the United States, and changes caused by requirements for stricter air pollution control. Meanwhile, various laboratories throughout the world are investigating the performance of new additives for increasing the performance of existing motor oils and industrial lubricating oils. The impact of this research will be to cause a change in the composition of the oils and a change in the consumption of oils for any given application.

Trends in internal combustion engine lubricating oil life do not appear well defined at this time. For example, the American Petroleum Institute recommends (49) that the user change his motor oil every three months or three thousand miles; automotive manufacturers have recommended changing oil at 6,000 mile intervals, under certain conditions. Although the trend has been for the amount of oil per mile of travel or use to decrease, there is enough uncertainty in today's picture to predict that this unit consumption could increase rather than decrease further. Thus, one can only conclude that gradual small changes in crankcase oil consumption and quality will occur in the near future.

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The very large investment that exists in both automotive and industrial lubricants plant capacity, will militate against rapid changes in the types of lubricants to be consumed. Any changes requiring the addition of synthetic oil process lines will necessitate the acquisition of new process equipment and the development of a market for the byproducts which would accompany such processes.

Other factors such as the potential introduction of hydrogen-fueled internal combustion engines which will probably use synthetic lubricants (127) may have an impact on oils in later years. However, in the near term, the hydrogen-based economy will not exert much influence on oil technology. Therefore, it may be predicted that over the near future, say 10 to 15 years, that petroleum-based lubricants will continue to be the major products used. Furthermore, it should be expected that a general increase in oil consumption for all uses will continue. Thus, we may expect an ever-increasing supply of waste industrial oil materials and waste automotive engine lubricating oil in the near future.

## SECTION IX

## SURVEY OF EXISTING LAWS AND REGULATIONS

A survey has been prepared to indicate the existing legal framework upon which the implementation of a waste oil recycling facility in the State of Maryland must be built. Only those laws and regulations which would uniquely affect such a facility have been considered. Those laws which would be equally applicable to any industrial facility are so numerous that they were not specifically considered here. For any specific system design, all laws relevant to it would have to be researched and analyzed.

This survey follows the same pattern that the waste oil recycling process takes. Laws applicable to the storage and collection of waste oils have been depicted first, including collector permit and holding tank requirements. Secondly, since the economics of operating a re-refining facility are affected by the existence of a Federal excise tax on lubricating oils, the nature and ramifications of this tax have been discussed. Finally, the State of Maryland and the Federal government have stringent labeling requirements for previously used oils; these measures have been described and analyzed herein.

### Storage Phase

Currently, there is no Maryland State law which requires a service station to have a waste oil holding tank of a specified minimum capacity. Very few local jurisdictions have such a requirement.

In spite of a lack of definite uniform requirements, the standard design of gasoline service stations includes the provision of a waste oil holding tank, usually underground and of a 550-gallon capacity.

There are ordinances in the various towns and counties of the State which do require some method of dealing with waste petroleum products from service station facilities. These ordinances fall into three general categories:

(1) On-site fire hazard control
(2) Sewage line explosion control and
(3) Pollution of drinking water supply

(See Appendix IIA, for a list of selected jurisdictions within Maryland and their laws relevant to waste oil storage and disposal.)

A typical on-site fire-hazard control ordinance requires waste petroleum products to be kept in steel drums or closed tanks and be removed from time to time to prevent undue accumulation (e.g., Montgomery County Code §86-36(K).

Sewage line explosion control ordinances, which also tend to serve a pollution control function, typically prohibit gasoline, kerosene or other inflammable liquids from being dumped into any sanitary or storm sewer (e.g., City of Annapolis Code §21-18). Additionally, service stations and other facilities using flammable liquids are sometimes required to have an oil separator installed to intercept any oily wastes which may be discharged into a storm or sanitary sewer (e.g., Building Officials Conference of America, BOCA, Basic Plumbing Code §P-1002.2 which has been adopted by various counties).

Nearly every county in Maryland has a provision in its ordinances prohibiting the pollution of its drinking water supply. These ordinances are not directed specifically towards waste oil products but do serve as an additional constraint on their disposal.

In addition to the various county ordinances, Maryland State Law (Ann. Code of Maryland, 1957, Art. 96A, §26) prohibits any person "to cause the pollution of any waters of the State or to place or cause to be placed any wastes in a location where they are likely to cause pollution of any waters of the State" or to "discharge any wastes into any waters of the State which would violate effluent standards or reduce the quality of such waters below the water quality standards established...."

## Collection Phase

The State of Maryland recently has enacted §26A of the Water Resources Law (Ann. Code of Maryland, 1957, Art. 96, §26A) which provides for the "regulation of transfer, storage, etc., of oil and other unctuous substances." It authorizes the Department of Water Resources to "...prescribe by regulation approved methods, facilities, standards, and devices for the transfer, storage, separating, removing, treating and disposing of oil and other unctuous substances for the purpose of preventing pollution of the waters of the State. No person shall engage in any commercial or industrial operation involving these activities unless approval is received from the Department in the form of a permit, indicating that the activities are in conformity with the prescribed regulations...."

Regulations currently are being considered by the Department of Water Resources to implement this permit requirement.

The October 20, 1972 issue of these regulations is attached in Appendix IIB.

These regulations have provisions for the regulation of marine oil transfer facilities, oil storage facilities, transfer and delivery of oil by truck, pipelines, used oil handling facilities and service stations.

## Federal Excise Tax

Prior to 1965, lubricating oil made from virgin crude oil was taxed at a rate of 6¢ per gallon, while re-refined or reprocessed oil was not subject to this excise tax. This 6¢ per gallon competitive edge had the effect of making re-refined oil an attractive substitute for virgin oils, particularly for applications such as non-highway use.

The Excise Tax Reduction Act of 1965, however, provided for an exemption from the general excise tax on virgin lubricating oil which allowed a refund to the ultimate user of all excise taxes paid on such oil used in other than highway motor vehicles (Int. Rev. Code of 1954, §6424). Additionally, the previously allowed exemption for blends of re-refined and virgin oil was disallowed (Rev. Rul. 57-204). Re-refiners, for the purposes of the non-highway use exemption, are not considered "users" within the meaning of this section and must pay the 6¢ per gallon tax on any new lube oils (e.g., bright stock) that they buy for blending. Re-refiners are thus excluded from the manufacturers' exemption when they purchase "bright stock" and other base oils for blending (26 C.F.R. §48.4091-2(b)(2)). Thus, when a re-refiner mixes 50 percent "bright stock" with the re-refined oil, for example, he must pay the 6¢ per gallon for the "bright stock" which, when mixed with a re-refined oil, is taxed again when sold. A gallon of blended oil carries a total of 9¢ per gallon excise tax.

## Labeling Requirements

In 1958, the Federal Trade Commission (FTC) ruled that the sale of re-refined oil without an indication of previous use was misleading to the consumer and ordered that any oil "composed in whole or in part of oil which has been reclaimed or in any manner processed from previously used oil..." be so indicated by "a clear and conspicuous statement to that effect on the container" (54 F.T.C. 1035, 1042).

In an attempt to comply with this ruling, the Double Eagle Refining Co. (respondents in the case) submitted sample labels which indicated on the side of the container that the oil had been "scientifically re-refined from previously used oil." This method of compliance was refused, and in 1964 a final order by the FTC (66 F.T.C. 1039) required a statement of previous use (rather than "re-refined") on the front of the container.

This rule is currently in effect and can be found at 16 C.F.R. §406.5. It requires a statement on the front of the container indicating that the oil has been "previously used" and prohibits the use of the word "re-refined" unless "the physical and chemical contaminants acquired through previous use have been removed by a refining process."

The State of Maryland also has a labeling law with respect to re-refined oils (Ann. Code of Md., 1951, Art. 27, §231). This prohibits the storage, sale or offer for sale of any "...reclaimed oils... so as to deceive the purchaser as to the nature, origin, quality, grade or identity, of the product so sold or offered for sale...." It also specifically requires any previously used and reclaimed or refined lubricating oils to have a clear indication "...setting forth such fact on the container, pump or distributing device used...."

## Use Requirements

U.S. Military specifications MIL-L2104B (engine oil) and MIL-L2105B (gear oil) require new oil regardless of the quality of re-refined oil. This has the effect of reducing the available outlets for re-refined oil, not only from military use but, because many municipal, state and private users buy on the basis of these specifications, from the same purchasers.

## Other Legislation

Included in Appendix II to this report are several pieces of legislation from other jurisdictions which indicate the various approaches that have been utilized.

The State of Massachusetts has enacted legislation and regulations for waste oil storage, collection and re-use (Appendix II-C).

The Federal Republic of Germany instituted a comprehensive waste oil law in 1968 (Appendix II-D).

On June 14, 1972, Congressman Vanik introduced a bill (H.R. 15502) entitled, "The National Oil Recycling Act", which attempts to deal with the problem of waste oil pollution by a comprehensive program to encourage waste oil recycling touching on many of the items mentioned in this report such as the Federal Excise Tax and the FTC labeling requirements (Appendix II-E).

# SECTION X

## LUBRICATING OIL BASE STOCKS

No discussion of waste oil reclamation would be complete without reference to the original (virgin) product manufacturing procedures and characteristics of the basic materials used to prepare lubricating oils.

Lubricating oil fractions are derived from three general classifications of hydrocarbons. These are the naphthenic oils, the paraffin oils and the aromatic oils. In general, the aromatic oils do not constitute an important source of lubricants because of their low viscosity index, high density and their reactive nature leading to the formation of insoluble products. Paraffinic oils containing branched chain paraffins are desirable in motor oil base stocks since they impart a high viscosity index. The straight chain paraffins are less desirable since they have a waxy nature and tend to increase the pour point of motor oil. Additionally, the paraffinic oils do not have good solvent power for the oxidation products formed during operation of an engine; however, the chemical structure of paraffinic materials is highly oxidation resistant. The naphthenic oils are saturated ring-shaped hydrocarbons and typically have high density and low viscosity indexes in the order of 50. They generally have lower flash points and higher volatility than paraffinic materials, but possess higher solvent power for the oxidized byproducts formed during engine operation.

Crude oil stocks for making lubricating oil originate from all parts of the world and can be made into what is commonly known as lubricating oil base stocks by various refining methods. These base stocks permit the production of lubricants possessing a range of viscosities by means of blending different oils together. The characteristics of some of these base oils are shown in Table 24. By tradition, the various paraffinic oils are known by names such as Solvent Neutral, Solvent and Solvent Bright Stock. Bright Stocks are very viscous materials as may be seen from their tabulated viscosities. These materials, together with various additives, are used to compound modern lubricants.

A brief mention should be made of the viscosity index, which is a measure of the oil's variability of viscosity with temperature. This is an important characteristic for all lubricants which undergo a change in temperature during use. The viscosity index (Dean and Davis) is based primarily on an empirical scale derived from two lubricating oil fractions, one of which originates from a Pennsylvania crude and is arbitrarily assigned a viscosity index of 100 and another crude oil from the Gulf Coast which yields a lubricating oil assigned a viscosity index of 0. Higher viscosity indexes reflect less viscosity change with variation in temperature. The viscosity index is calculated from the viscosities of these two standard materials at two temperatures: 100°F and 210°F. All other lubricating oils are compared with the viscosity variations of these two standardized reference samples.

## TABLE 24
## CHEMICAL AND PHYSICAL CHARACTERISTICS OF NAPHTHENIC AND PARAFFINIC BASE OILS

| Names of Base Oils | Specific Gravity (59°F) | Color (NPA) | Flash Point (°F) | Viscosity @ 122 F (Centistokes) | Viscosity Index (Dean & Davis) | Pour Point (°F) | Conradson Carbon (%) | Acid Number (mg.KOH/g) |
|---|---|---|---|---|---|---|---|---|
| I. Paraffinic Oils | | | | | | | | |
| 100 Solvent Neutral | .865 | 1.5 | 392/428 | -- | 95/102 | 10/5 | 0.01 | 0.01 |
| 150 " | .865/.885 | 1.75-2 | 392/401 | 19/23 | 95 | 5 | 0.06 | 0.01/0.1 |
| 200 " | .870/.890 | 2 | 410 | 24/28 | 95 | 10/5 | 0.06 | 0.05/0.1 |
| 350 " | .880/.895 | 3.5 | 419 | 39/47 | 95 | 16 | 0.1 | 0.1 |
| 400 " | .880/.895 | 3.5 | 446/455 | 46/56 | 95 | 16/5 | 0.05/0.1 | 0.01/0.1 |
| 500 " | .880/.895 | 2.5/3.5 | 446/455 | 57.8/62.5 | 95 | 16/5 | 0.05/0.1 | 0.05/0.1 |
| 600 " | .880/.895 | 3.5 | 446/464 | 66/74 | 95 | 16/14 | 0.15 | 0.1 |
| Solvent Bright Stock | .890/.920 | 4-7 | 527/554 | 243/290 | 95 | 18/14 | 0.6/0.9 | 0.05/0.1 |
| 350 Solvent | .885/.900 | 3-4 | 410 | 39/47 | 85 | 16 | 0.15 | 0.1 |
| 500 " | .895/.925 | 3-4 | 392/428 | 49/57 | 65/70 | 10/5 | 0.2 | 0.05/0.1 |
| II. Naphthenic Oils | | | | | | | | |
| V 4.5 | .895/.910 | 2-2.5 | 374/392 | 29/35 | 35/45 | -13 | 0.03/0.05 | 0.05 |
| V 7.5 | .900/.922 | 3-3.5 | 392 | 55.5/61 | 35/45 | - 5 | 0.05/0.1 | 0.05 |
| V 18 | .900/.928 | 3.5-4 | 464/473 | 122/137 | 30/45 | 16/5 | 0.15/0.4 | 0.05 |

The viscosity index of typical unrefined lubricating oil fractions produced by distillation of crudes varies considerably from source to source. Indexes may range from 0 for the Gulf Coast crudes to over 105 for the Middle East crudes. Table 25 lists some of the viscosity indexes of typical lubricating oil fractions from various crudes. In the current scene, the viscosity index of the base oil fractions is not as important as in prior years because of the ability to use certain additives to impart the desired viscosity index. Because of the importance of lubricating oil manufacturing technology as it applied to waste oil recovery, a number of important refining processes for manufacturing base oil stocks will be presented and discussed first.

An overview of the general scheme for base oil production is shown in Figure 5. Figure 6 illustrates the vacuum distillation step starting with reduced crude oil to produce base oil "cuts". Major process streams, in the opinion of the authors, are indicated by wide lines and arrows; this device is for purposes of clarification, not an attempt to simplify processes beyond the levels indicated in the appropriate references. Reduced crude oil comprises the higher boiling point materials remaining after distillation of crude oil and does not contain naphthas, kerosene or low boiling gas oils, most of which have been removed in the first crude oil processing step. Vacuum distillation of the reduced crude gives rise to three major products: a relatively low boiling gas oil which is not used for lubricant base stocks; a series of distillates (cuts 1, 2 and 3) which are used for base oils; and residual asphalt. These base stocks are then refined by further treatment including such processes as extraction, dewaxing, clay treating, propane de-asphalting, and hydrofining. These partially refined base stocks have characteristics illustrated in Figure 7. These distillation curves show the widely varying characteristics of the fractions produced for lubricating oil base stock production. Further treatment by extractive and chemical processing is used to convert these fractions into lubricating oil base stocks.

Another important solvent refining process employs furfural treatment which results in the reduction or removal of aromatic and naphthenic hydrocarbons from the lubricating oil fraction. Figure 8 depicts the general operation of the furfural solvent refining process.(51)

Another base oil refining process is dewaxing for the removal of high melting point paraffins which raise the pour point of motor oils. Generally, the dewaxing process comprises extraction of the wax followed by separation of the solvent from the purified oil phase and from the byproduct wax. A typical dewaxing process using a ketone (for example, methylethylketone) is shown in Figure 9.(51) A similar process using a mixture of methylethylketone and benzene is shown in Figure 10. In both examples illustrated, the oil to be refined is mixed with the solvent and cooled to the point at which paraffin crystals precipitate. Subsequently, these are filtered out and the solvent distilled off of both the purified dewaxed oil fraction and the solid paraffin crystal fraction.

## TABLE 25

## THE EFFECT OF CRUDE OIL ORIGIN ON VISCOSITY INDEX OF LUBRICATING OIL FRACTIONS

(Ref. 7, 46, 47)

| Origin of Crude | Viscosity Index |
|---|---|
| Gulf Coast | 0 |
| Peruvian | 20 |
| Webster, USA | 34 |
| Columbian | 40 |
| Venezuela | 57 |
| East Texas | 60 |
| Mid-Continent | 80 |
| Aramco - Middle East | 97 |
| Pennsylvania | 100 |

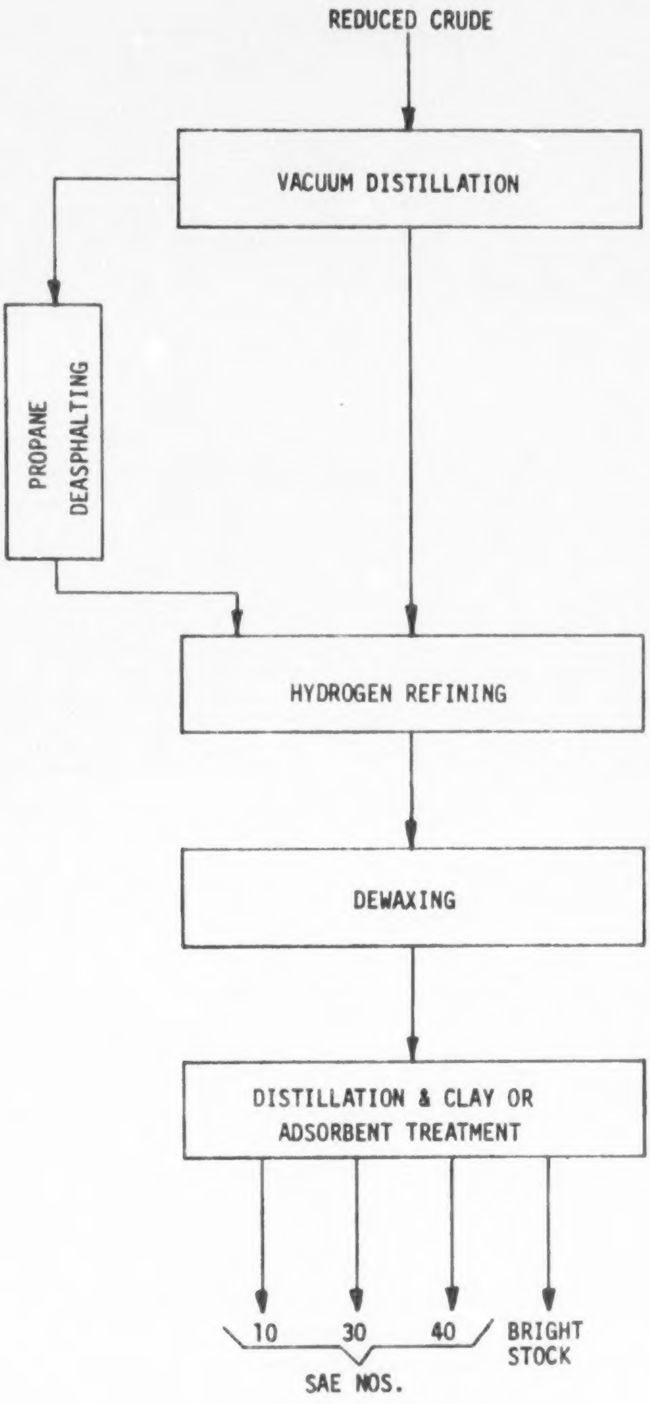
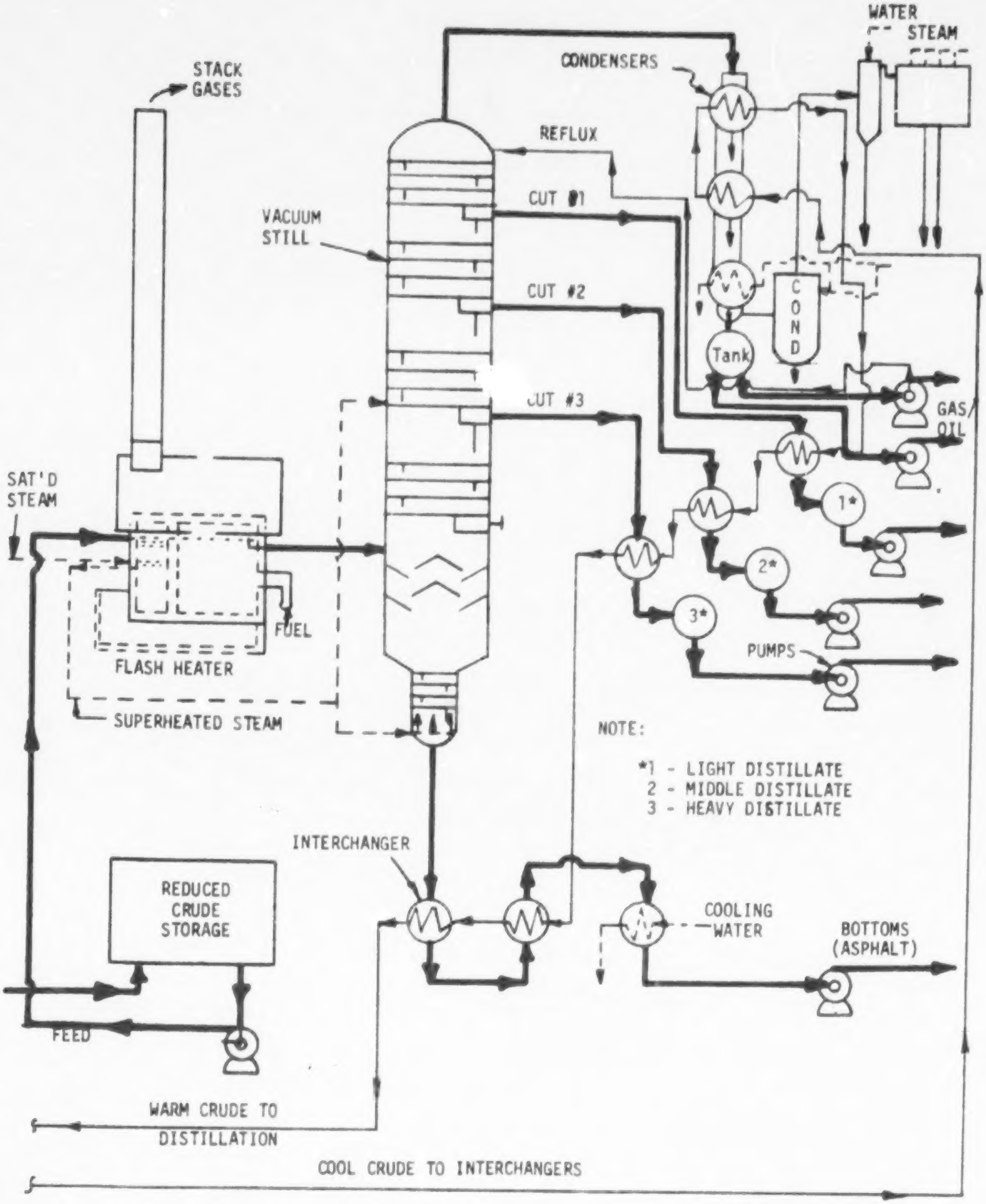

REDUCED CRUDE
VACUUM DISTILLATION
PROPANE DEASPHALTING
HYDROGEN REFINING
DEWAXING
DISTILLATION & CLAY OR ADSORBENT TREATMENT
10
30
40
BRIGHT STOCK
SAE NOS.

FIG. 5 GENERAL PROCESS SCHEME FOR BASE OILS (Ref. 7)


WATER
STEAM
CONDENSERS
STACK GASES
REFLUX
CUT #1
VACUUM STILL
CUT #2
COND
Tank
CUT #3
GAS/OIL
SAT'D STEAM
1*
2*
3*
FUEL
PUMPS
FLASH HEATER
SUPERHEATED STEAM
INTERCHANGER
REDUCED CRUDE STORAGE
COOLING WATER
BOTTOMS (ASPHALT)
FEED
WARM CRUDE TO DISTILLATION
COOL CRUDE TO INTERCHANGERS

NOTE:

*1 - LIGHT DISTILLATE
2 - MIDDLE DISTILLATE
3 - HEAVY DISTILLATE

Fig. 6. Vacuum Distillation of Reduced Crude to Produce Base Oil Materials (Ref. 7)

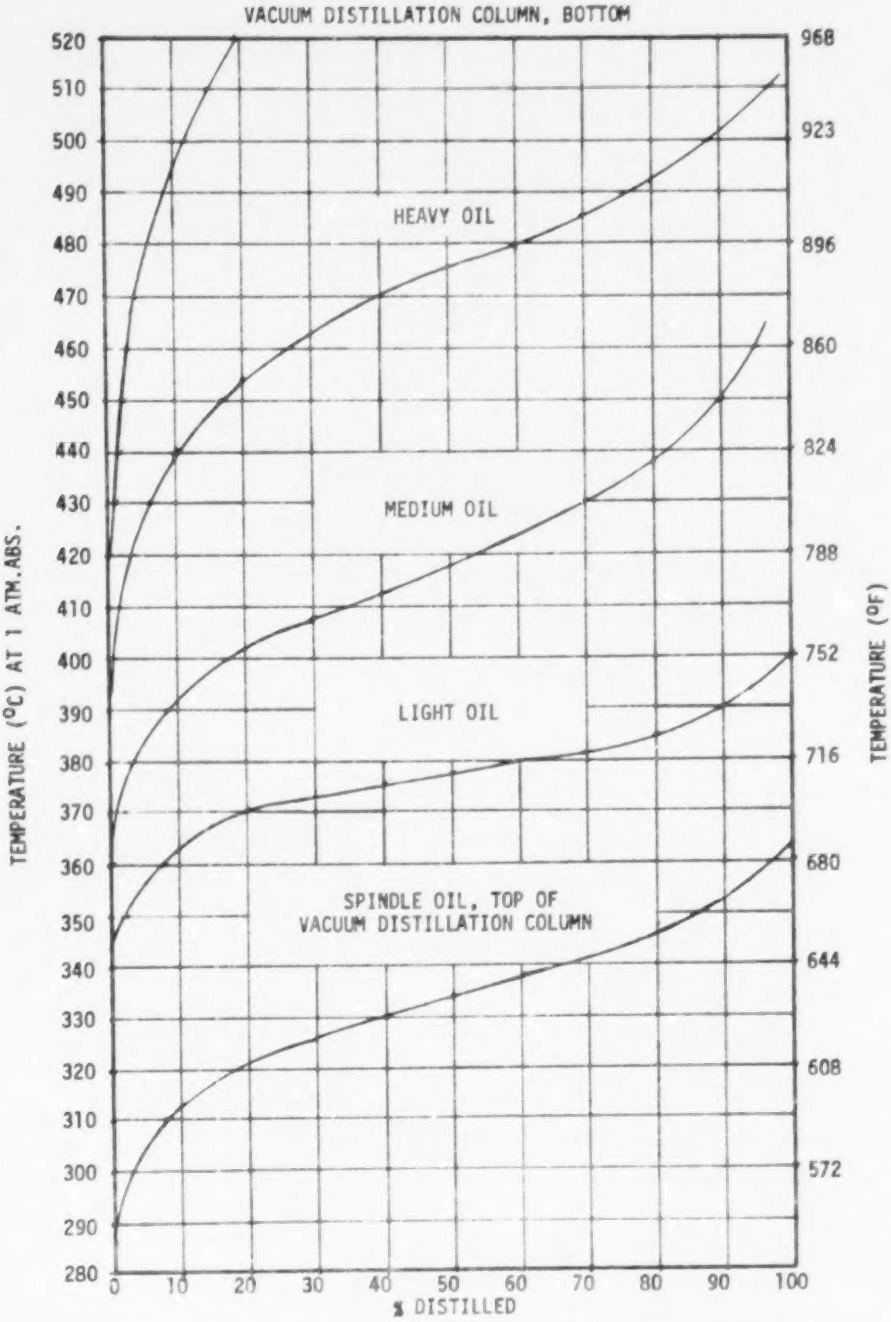


FIGURE 7. DISTILLATION CURVES OF LUBRICATING OIL FRACTIONS (VACUUM DISTILLED REDUCED CRUDE)

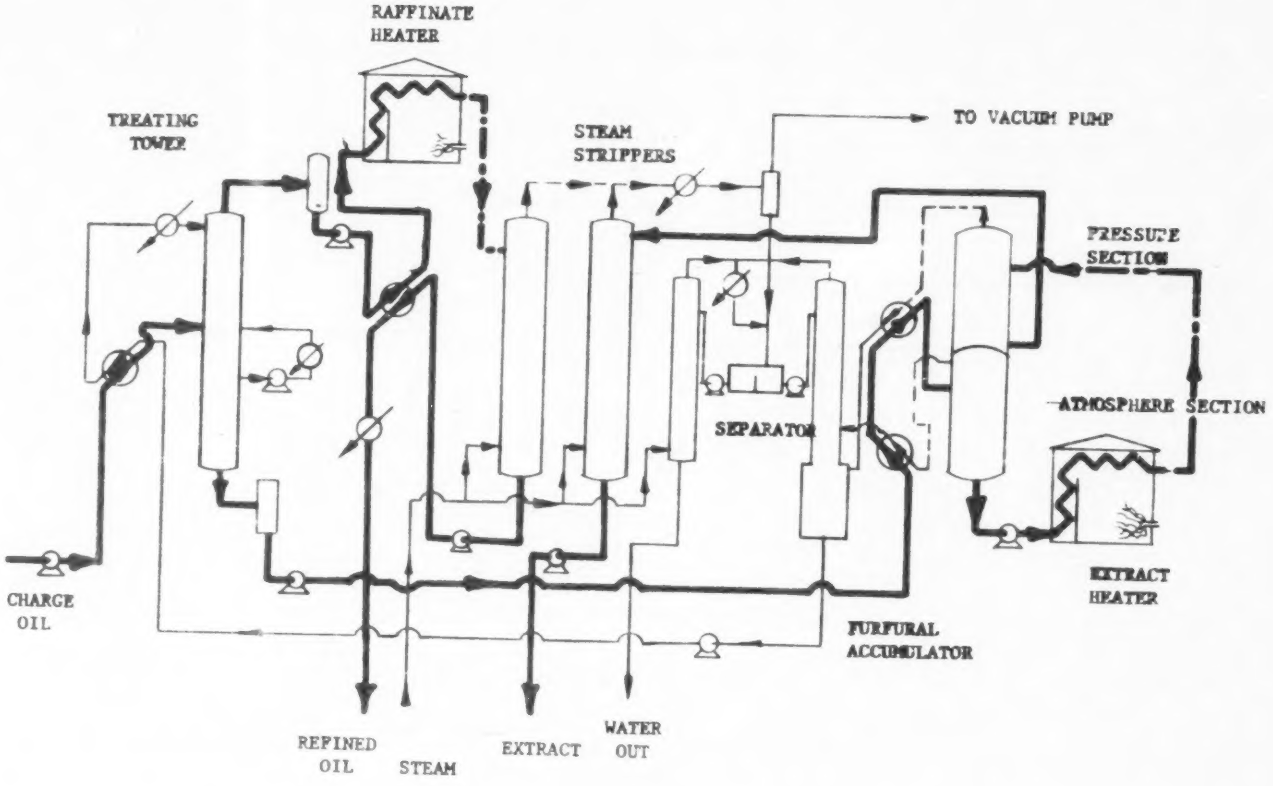

RAFFINATE HEATER
TREATING TOWER
STEAM STRIPPERS
TO VACUUM PUMP
PRESSURE SECTION
ATMOSPHERE SECTION
SEPARATOR
EXTRACT HEATER
FURFURAL ACCUMULATOR
CHARGE OIL
REFINED OIL
STEAM
EXTRACT
WATER OUT
PUMP
HEAT EXCHANGER

FIGURE 8 . FURFURAL SOLVENT REFINING PROCESS FOR BASE SYOCKS (Ref. 51)

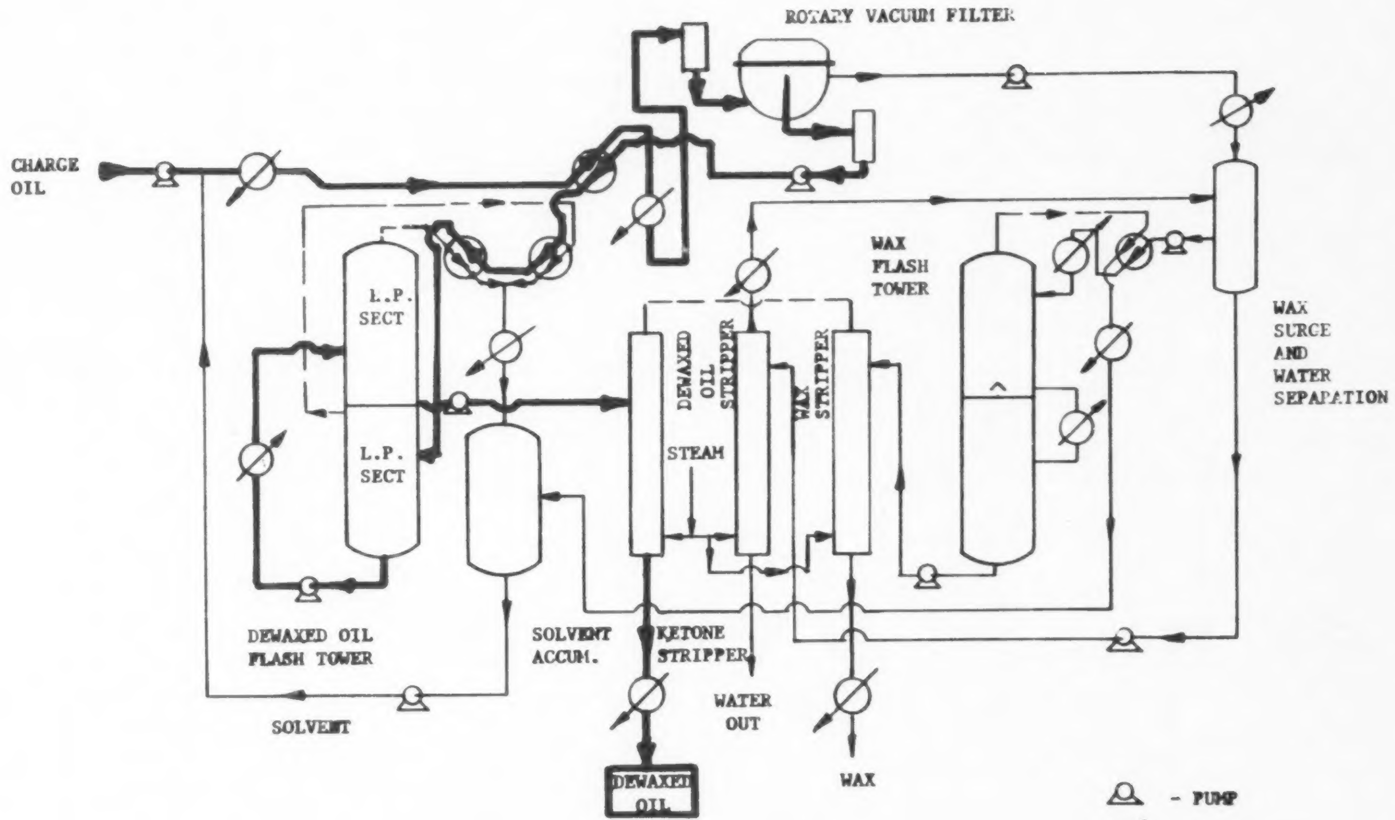

ROTARY VACUUM FILTER
CHARGE OIL
L.P. SECT
L.P. SECT
WAX FLASH TOWER
WAX SURGE AND WATER SEPARATION
DEWAXED OIL STRIPPER
WAX STRIPPER
STEAM
DEWAXED OIL FLASH TOWER
SOLVENT ACCUM.
KETONE STRIPPER
WATER OUT
SOLVENT
DEWAXED OIL
WAX
- PUMP
- HEAT EXCHANGER

FIGURE 9. DEWAXING PROCESS FOR LUBE OIL BASE STOCKS (Ref. 51)

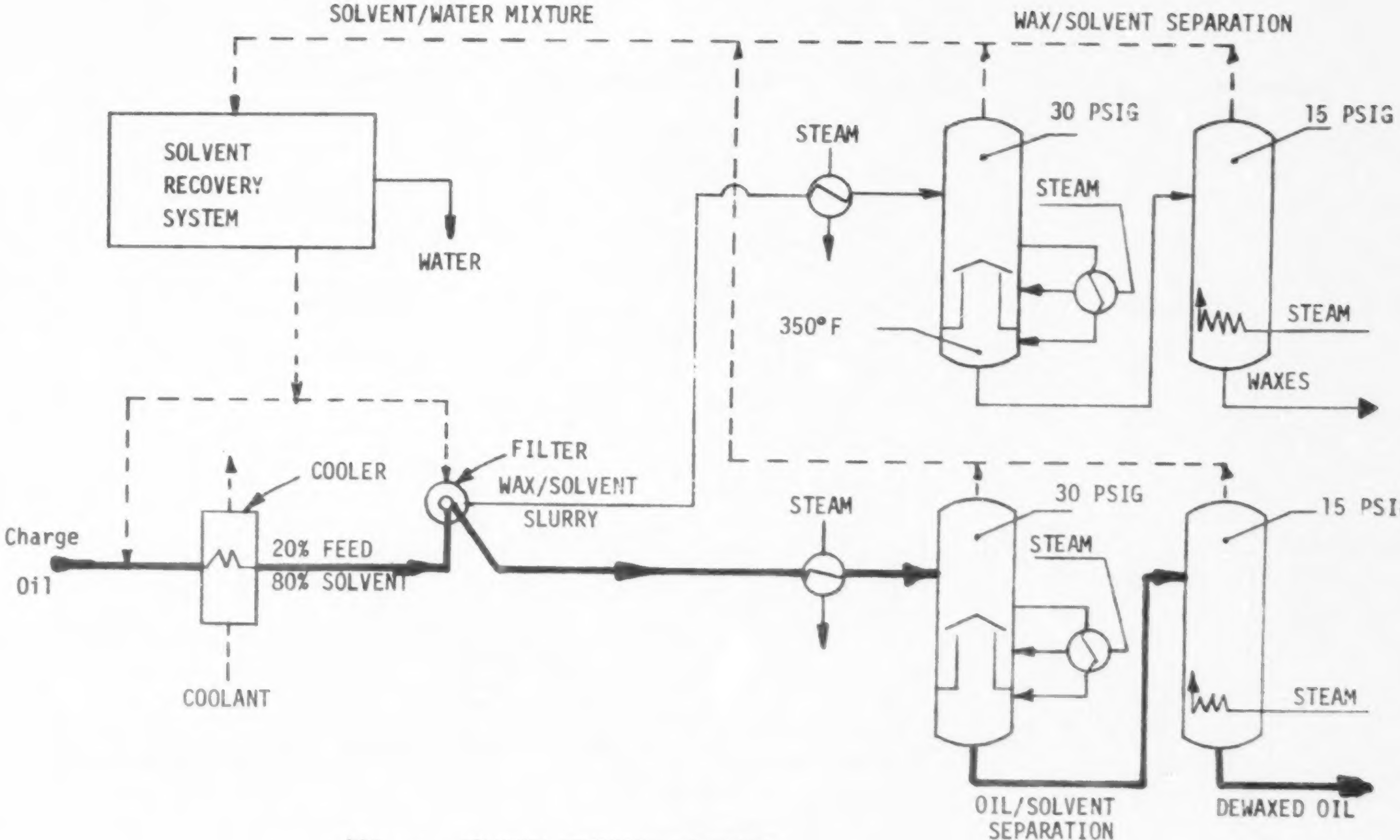

SOLVENT/WATER MIXTURE
WAX/SOLVENT SEPARATION
SOLVENT RECOVERY SYSTEM
WATER
STEAM
30 PSIG
STEAM
15 PSIG
350° F
STEAM
WAXES
COOLER
FILTER
WAX/SOLVENT SLURRY
Charge Oil
20% FEED
80% SOLVENT
COOLANT
STEAM
30 PSIG
STEAM
15 PSIG
STEAM
OIL/SOLVENT SEPARATION
DEWAXED OIL

FIG. 10 SOLVENT DEWAXING SCHEMATIC
(Ref. 51)

Another process used in base oil preparation is adsorptive treatment with clay, usually used in small amounts of two to five percent added to the oil stock, contacted at high temperature, and then separated from the oil by filtration. The adsorptive properties of the clay are such as to remove materials contributing to carbon residue, color, acidity, and sulfur. Figure 11 illustrates this process.

An important chemical process used for refining base oil stocks, particularly for industrial grade lubricants, is the acid process which uses concentrated sulfuric acid mixed with the oil stock and results in the removal of the reactive asphaltic materials and various low viscosity index constituents. An example of acid treatment processing is shown in Figure 12. Although sulfuric acid treatment has been replaced largely by solvent refining methods, it is still used by a number of producers to manufacture specific types of base lubricating oil stocks. An important characteristic of the sulfuric acid process is its ability to produce naphthenic base oils very low in carbon residues but possessing good solvent power for oxidized oil bodies. Two major drawbacks of the sulfuric acid process are the decreased yield in finished oil due to losses in the sulfuric acid sludge and the requirement to get rid of large quantities of waste sulfuric acid.

An important chemical process in base oil manufacture is hydrogenation in which the oil to be refined is mixed with gaseous hydrogen at high pressure in the presence of a catalyst. Figure 13 illustrates this refining process. When the degree of hydrogenation is mild, that is the amount of cracking is held to a minimum and the amount of hydrogenation is controlled to affect mostly the aromatic content of the oil, the process is known generally as hydrofinishing. When the degree of hydrogenation is severe and a great deal of cracking occurs, the oils produced by this process tend to be more paraffinic. These processes frequently are referred to as hydrotreating, hydrofining or hydrocracking and are generally carried out at higher temperatures and pressures (e.g., 1700 psi, 750°F).

The processes just described result in a wide spectrum of lubricant base stocks which can be blended and mixed with various additives to produce thousands of different types of lubricants for various types of applications. These additives are put into the base oils for three basic reasons: 1) to improve the lubricant performance, 2) to protect the lubricant and 3) to protect the lubricated surface. A review of these additives, their function, composition and application is shown in Table 26 (7,53).

Various combinations of additives and base oils are blended either in batch or continuous lubricating oil blending plants to produce lubricating oils for specific applications. Equipment for such plants consist of tanks, mixers, heating equipment, metering pumps, packaging machinery and a suitable laboratory test facility. Large modern blending and packaging plants can process more than two million gallons of lubricant per month.

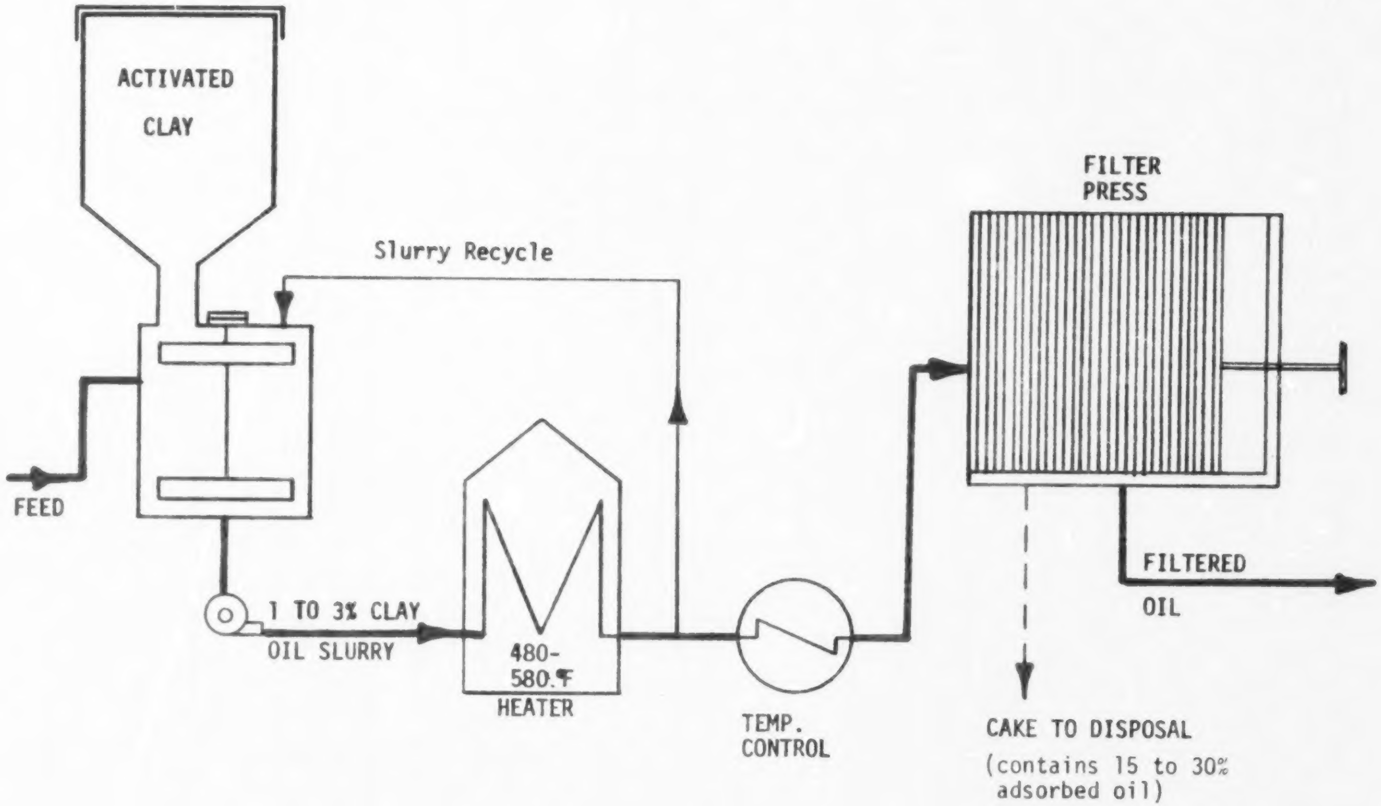

ACTIVATED CLAY
FEED
Slurry Recycle
1 TO 3% CLAY OIL SLURRY
480-580.°F HEATER
TEMP. CONTROL
FILTER PRESS
FILTERED OIL
CAKE TO DISPOSAL
(contains 15 to 30% adsorbed oil)

FIGURE 11 CLAY TREATMENT OF BASE OIL STOCKS.
(Ref. 51)

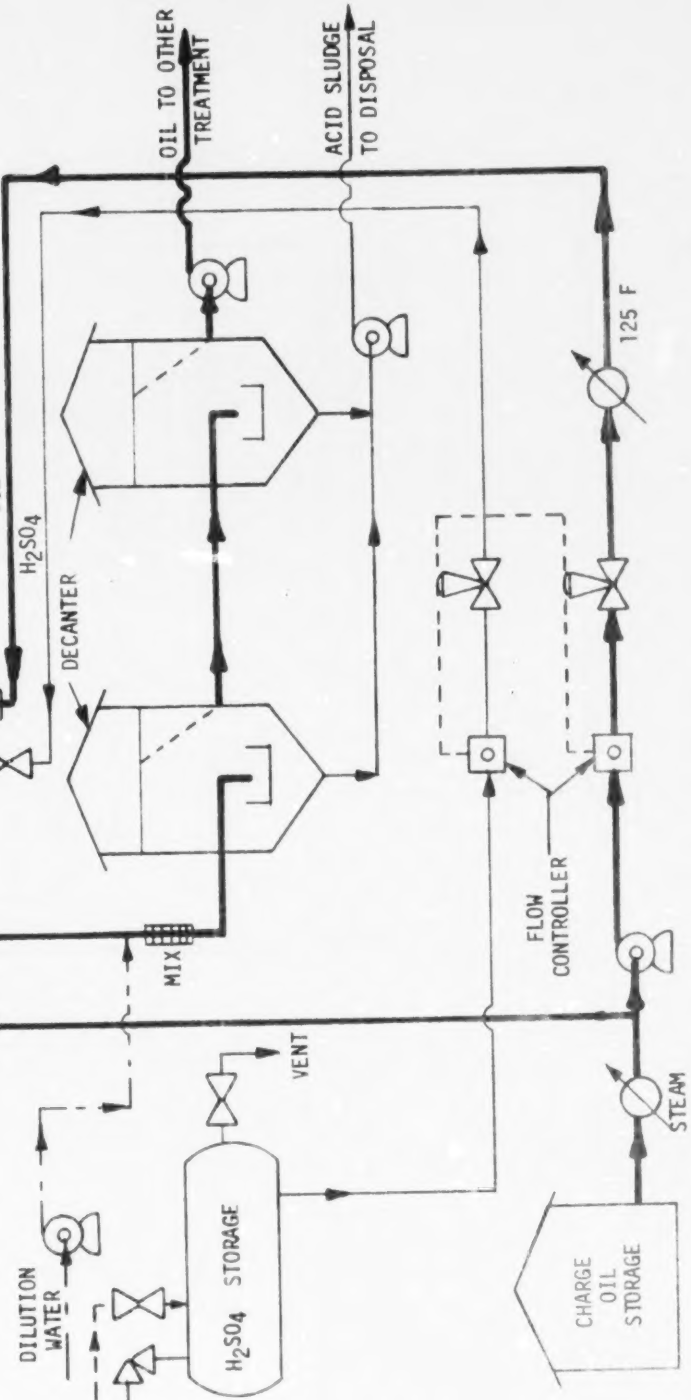

OIL TO OTHER TREATMENT
ACID SLUDGE TO DISPOSAL
OIL
$H_2SO_4$
DECANTER
MIXER
MIX
125 F
FLOW CONTROLLER
VENT
STEAM
DILUTION WATER
$H_2SO_4$ STORAGE
CHARGE OIL STORAGE

FIG. 12 ACID TREATMENT OF BASE OIL STOCKS
(Ref. 7)

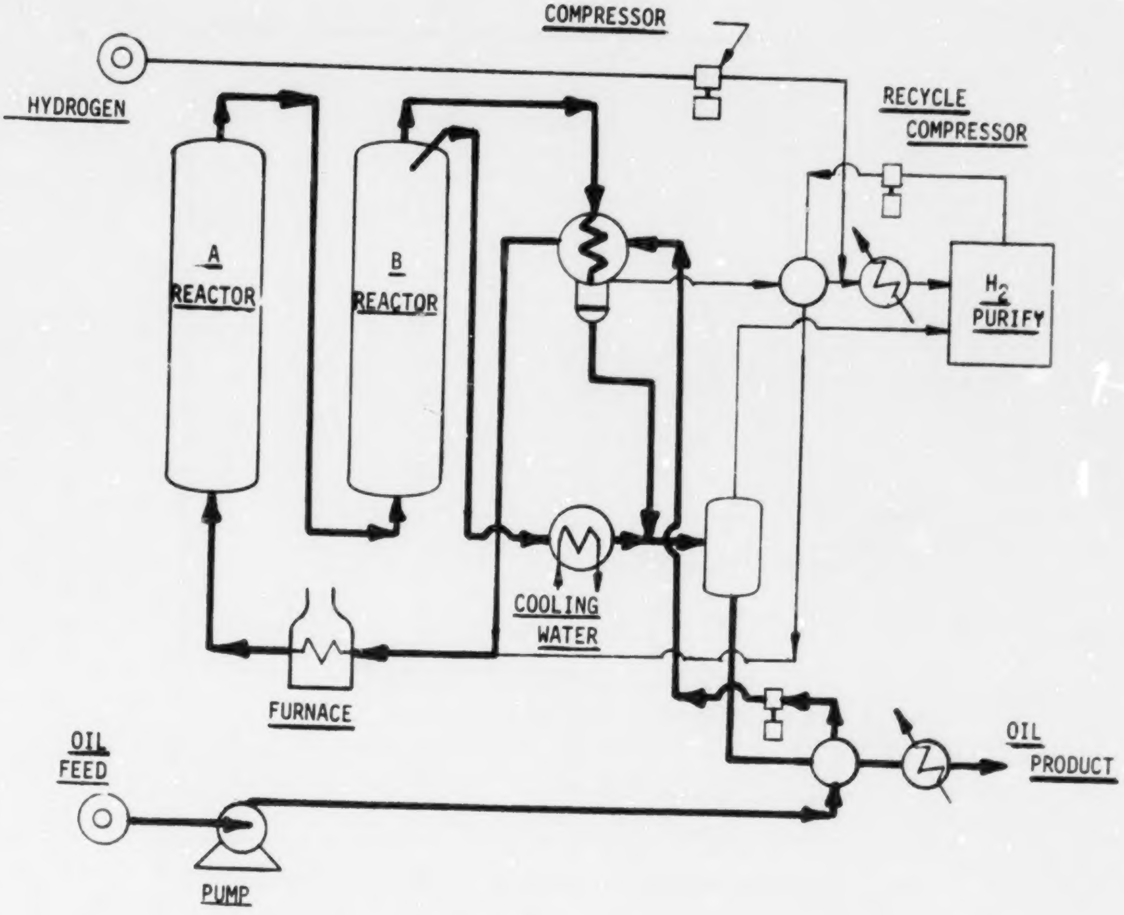

COMPRESSOR
HYDROGEN
RECYCLE
COMPRESSOR
A
REACTOR
B
REACTOR
$H_2$
PURIFY
COOLING
WATER
FURNACE
OIL
FEED
PUMP
OIL
PRODUCT

FIGURE 13 HYDROGENATION OF BASE OILS

## TABLE 26

## COMPOSITION, APPLICATION AND FUNCTION OF LUBRICATING OIL ADDITIVES

| Name of Additive | Composition | Application | Function |
|---|---|---|---|
| Corrosion Inhibitor | Zn and Ba dithiophosphates, dithiocarbamates, metal sulfonates and sulfurized terpenes | IC engines, alloy bearings, ATF | To react with metal surfaces to form a corrosion-resistant film |
| Rust Inhibitor | Sulfonates, alkylamines, amine phosphates, alkenylsuccinic acids, fatty acids and acid phosphate esters | IC engines, turbines, electric and mechanical rotary machinery, fire-resistant hydraulic fluids | To react chemically with steel surfaces to form an impervious film |
| Antiodorant | Perfumes, formaldehyde compounds | With EP additives | To mask odors |
| Antiseptic | Alcohols, phenols, chlorine compounds | With water added to oil-emulsions | To inhibit microorganisms |
| Antioxidant | Sulfides, phosphites, amines, phenols, dithiophosphates | IC engines, turbines, and rotary machinery | To inhibit oxidation of oil |
| Antifoam | Silicones, synthetic polymers, waxes | Same as rust inhibitors, excluding ball bearings | To permit air bubbles to separate from oil |
| Detergent | Sulfonates, phosphonates, phenates, alkyl substituted salicylates combined with barium, magnesium, zinc calcium | IC engines under steady load | To neutralize acids in crankcase oils to form compounds suspended in oil |
| Dispersant | Alkenyl succinimides, alkyl-acrylic polymers, ashless compounds | IC engines at low temperatures and variable loads | To disperse contaminants in the lubricant |

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Abbreviations: IC = Internal Combustion Engine; ATF = Automatic Transmission Fluid; EP = Extreme Pressure

## TABLE 26 (Continued)

## COMPOSITION, APPLICATION AND FUNCTION OF LUBRICATING OIL ADDITIVES

| Name of Additive | Composition | Application | Function |
|---|---|---|---|
| Metal Deactivator | Organic dihydroxyphosphines, phosphites and sulfur compounds | IC engines, turbines, electric motors, air compressors, hydraulic oils | To form protective film on running surfaces to inhibit corrosion reactions |
| Color Stabilizer | Amine compounds | When heat and oxidation darken oil | To stabilize oil color |
| Viscosity Index Improver | Isobutylene polymers and acrylate copolymers | IC engines, electric motors, air compressors, hydraulic oils | To retard loss of viscosity at high temperatures |
| Pour Point Depressant | Polymethacrylates, polyacrylamides, alkylated naphthalenes and phenols | IC engines, gears, bearings, transmissions | To prevent congealing of oil at low temperatures |
| Extreme Pressure Additive | Organic compounds with sulfur, phosphorous, nitrogen, halogens, carboxyl or carboxalate salt | IC engines, turbines, motors, hydraulic oils, gears, rollers and ball bearings | To form low-shear-strength film providing lubrication at startup and at high bearing loads |
| Antiwear Additive | Chlorinated waxes, organic phosphates, lead naphthenate | As above | As above except for running condition |
| Tackiness Agent | Polyacrylates and polybutenes | Gear enclosures from which oil must not drop | To improve adhesive qualities of base oil |
| Emulsifier | Surfactants, sulfonates, naphthenates and fatty acid soaps | Soluble cutting oils | To reduce interfacial tension and permit formation of water-oil emulsion |

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Abbreviations: IC = Internal Combustion Engine; ATF = Automatic Transmission Fluid; EP = Extreme Pressure

## SECTION XI

## PHYSICAL AND CHEMICAL PROCESSES FOR RE-REFINING WASTE OILS

There are a large number of physical and chemical processes which have been developed for reclamation, re-refining and reprocessing of industrial and automotive lubricants. Some of these processes are directed toward upgrading the oil only slightly for use in the same machines while other processes are very elegant and complicated and produce a whole range of petroleum products. Many industrial operations using significant quantities of lubricating oils maintain their own purification and renovation systems. Some of these shall be discussed here since they have application for all waste oil purification processes.

The processing of crankcase oils from diesel and gasoline engines has developed over the years from simple settling, filtration and dehydration processes into complicated petrochemical-type processes producing a multiple product line. Because of the complexity of crankcase oils, their renovation and separation generally is more complicated. For example, typical additives to the hydrocarbon base stocks used for motor oil manufacture may include materials to improve load carrying ability, anti-oxidants, antifoam additives, corrosion inhibitors, detergents, dispersants, pour point depressants, viscosity index improvers and additives to alter the color of the oil. Detergents and dispersants generally consist of salts of the family of metals including aluminum, magnesium, zinc, calcium, barium and anionic groups such as phenyl/stearates, naphthenates, salicylates, sulfonates and phenates.

To prevent the effects of acidity encountered in automotive engines, there is usually a large excess of metal compounded with the detergent and dispersants. In addition, materials known as pour point improvers or depressants are added to motor oils to lower the temperature at which the oil can still function properly. Such materials consist of polymethacrylates, polyacrylates and other materials.

A variety of antioxidant and anti-corrosion additives are also used. These inhibit the formation of oxidized oil products and the formation of lacquer and other deposits in the engine. In addition, they retard corrosion of vital engine parts. Historically, the oxidation and corrosion inhibitors have consisted of olefin and terpene sulfides, aromatic amines, phosphorous-sulfur compounds, metal salts of alkyldithiophosphates such as zinc or barium dithiophosphate, selenium compounds such as the dialkylselenides and orthoalkylphenols such as diterbutylphenol and mercaptans. Currently, the zinc dialkylthiophosphates appear to be the most popular for use as oxidation inhibitors.

To control foaming in engine oils, small amounts of antifoam are added; organosilicon compounds are the most widely used for this purpose. To maintain control over the changes in viscosity as the engine oil temperature changes, various viscosity index improvers are added to motor oil base stocks. Typically, these materials consist of such compounds as polyisobutenes, polymerized alkylstyrenes, polymethacrylates and polyacrylates.

Continuous exposure of the motor oil to the crankcase environment which includes engine combustion products, results in the formation of a whole host of other compounds, many of which have not been identified. The process of lubrication and combustion in the engine leads to the formation of suspended carbon particles, high molecular weight hydrocarbons, wear particles, the introduction of the high boiling fractions of the fuel itself and the formation of materials generally classified as sludge. In addition, the hot gases coming in contact with the motor oil form precursers which have been identified as nitro compounds (54) of motor oil; these compounds have been shown to initiate sludging. Because of their volatility in certain distillation processes, they are frequently carried over the main body of distillate where they continue to cause chemical reactions leading to further precipitation of insoluble bodies.

A large number of re-refining, reprocessing and similar purification and separation operations have been devised for recycling waste oils into reusable products, either for their original intended use or for new uses.

A typical lubricating oil re-refining procedure (23) reported by Skallerup is shown in Figure 14. This process is mostly a physical one and is illustrative of many of the crankcase oil re-refining operations. A more detailed view of reprocessing to produce reclaimed motor oils and byproduct fuel is shown in Figure 15. It should be noted that this is not purely a physical process but combines both physical and chemical treatment. Figure 15 compares two types of processes, an old process and an alternate process. The old process uses large quantities of sulfuric acid and clay, producing wastes which must be disposed of. The improved process eliminates the sulfuric acid treatment but retains the clay treatment. This alternate process appears to produce re-refined oils of suitable quality without yielding large quantities of waste acid sludge. However, it still produce waste clay which must be disposed of properly.

A more detailed view of the equipment and processes used for these combined physical/chemical reprocessing operations is shown in Figure 16. The major process steps shown herein consist of decantation to separate out heavy solids and water, stripping to remove residual water and low boiling contaminants such as gasolines or solvents; sulfuric acid treatment to remove oxidized products and cause flocculation of suspended carbon; neutralization to remove any excess sulfuric acid; clay treatment at elevated temperatures to remove remaining acidic materials and trace contaminants; and finally, filtration to remove the clay. The process as shown in Figure 16 has been used extensively both in the U.S. and abroad for reclamation of spent crankcase oils. Since reprocessing by this technique removes many of the additives and changes the physical and chemical characteristics of the oil, it is necessary to add the proper amount of new additives, additional base stocks such as Bright Stock and other Solvent Neutral, and naphthenic oils, to produce the desired end product specifications.

A purely physical process using settling and distillation techniques is shown in Figure 17. In this process, waste crankcase oils are settled to remove heavy solids and water and then charged to a flash heater and tower combination where residual water and low boiling naphtha is removed. The

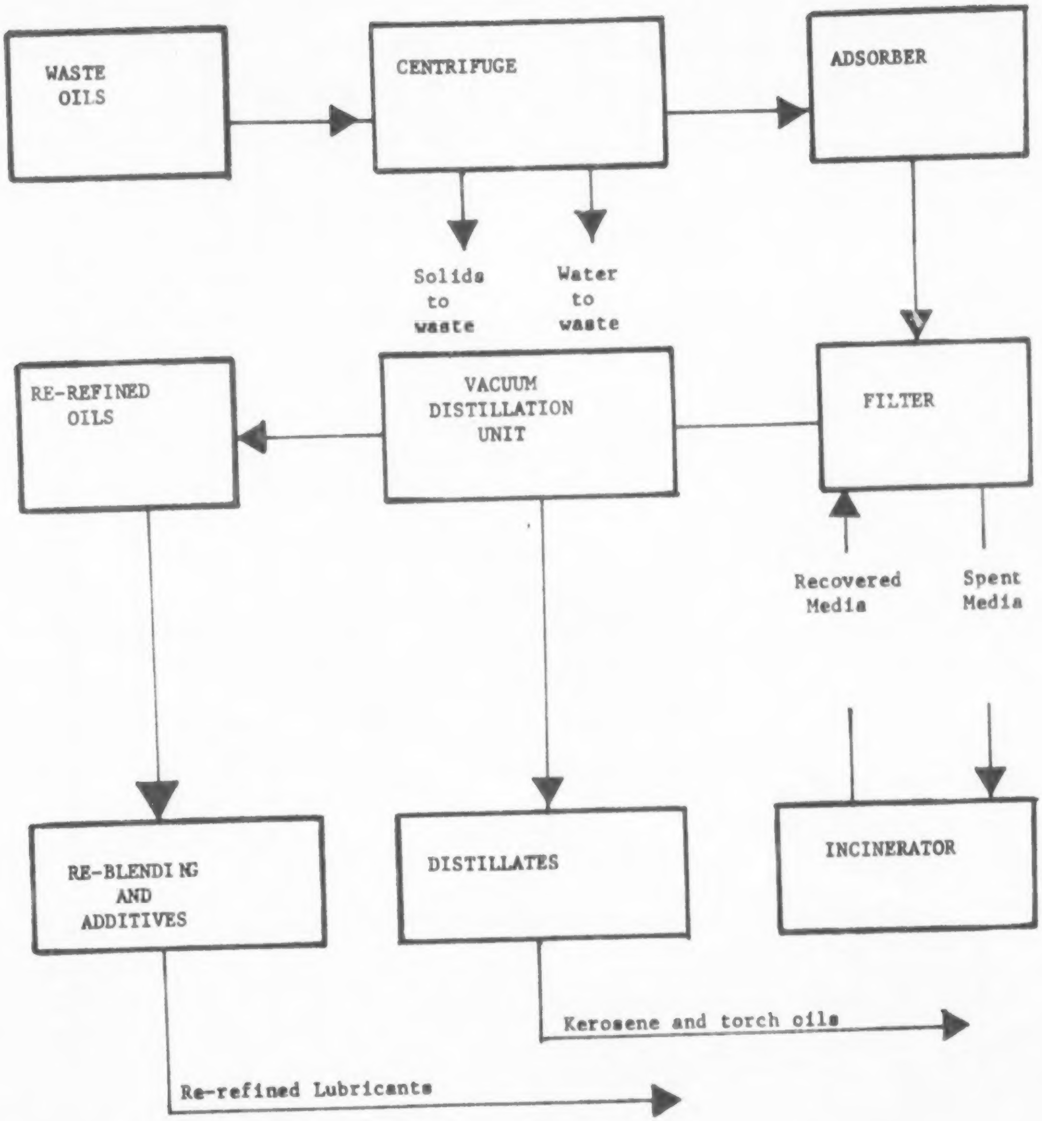

WASTE OILS
CENTRIFUGE
ADSORBER
Solids to waste
Water to waste
RE-REFINED OILS
VACUUM DISTILLATION UNIT
FILTER
Recovered Media
Spent Media
RE-BLENDING AND ADDITIVES
DISTILLATES
INCINERATOR
Kerosene and torch oils
Re-refined Lubricants

FIGURE 14. LUBRICATING OIL RE-REFINING SCHEMATIC.
(Ref. 23)

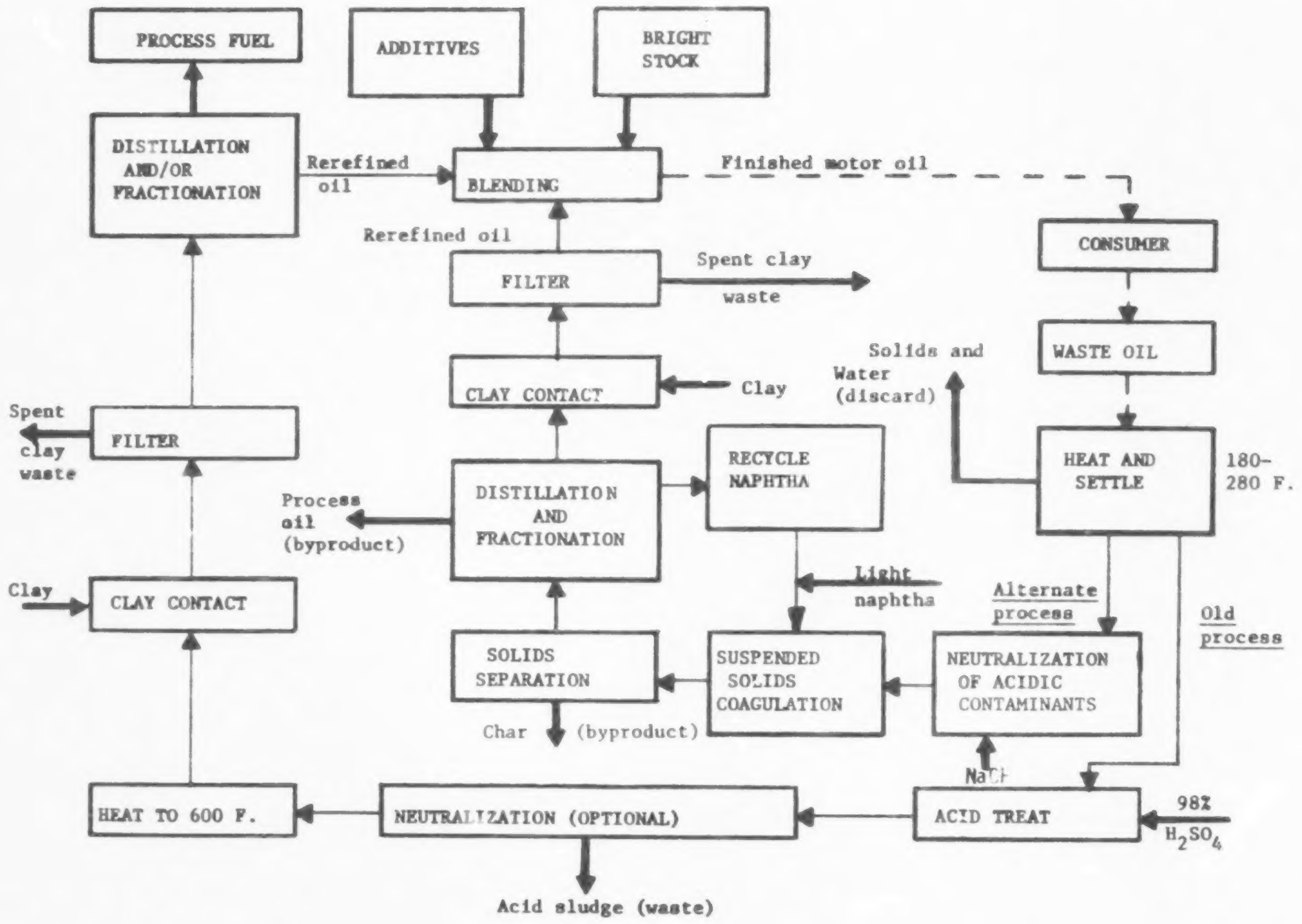

PROCESS FUEL
ADDITIVES
BRIGHT STOCK
DISTILLATION AND/OR FRACTIONATION
Rerefined oil
BLENDING
Finished motor oil
CONSUMER
Rerefined oil
FILTER
Spent clay waste
WASTE OIL
Solids and Water (discard)
CLAY CONTACT
Clay
Spent clay waste
FILTER
RECYCLE NAPHTHA
HEAT AND SETTLE
180-280 F.
Process oil (byproduct)
DISTILLATION AND FRACTIONATION
Light naphtha
Alternate process
Old process
Clay
CLAY CONTACT
SOLIDS SEPARATION
SUSPENDED SOLIDS COAGULATION
NEUTRALIZATION OF ACIDIC CONTAMINANTS
Char (byproduct)
NaOH
HEAT TO 600 F.
NEUTRALIZATION (OPTIONAL)
ACID TREAT
98%
H2SO4
Acid sludge (waste)

FIGURE 15. COMPARISON OF CRANKCASE OIL RE-REFINING PROCESSES.

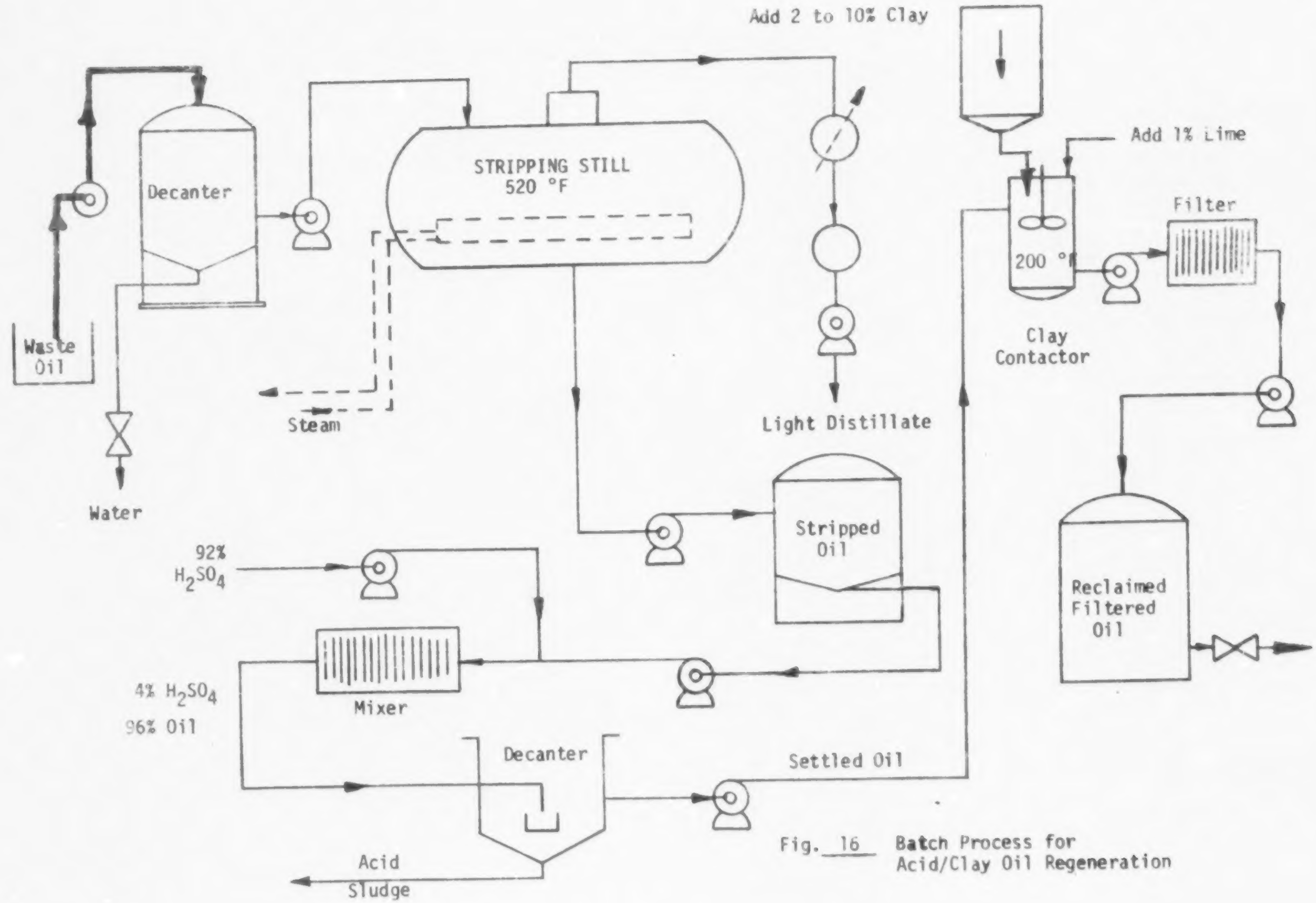

Add 2 to 10% Clay
Add 1% Lime
Decanter
STRIPPING STILL
520 °F
Waste Oil
Water
Steam
Light Distillate
Clay Contactor
200 °F
Filter
Stripped Oil
Reclaimed Filtered Oil
92% $H_2SO_4$
4% $H_2SO_4$
96% Oil
Mixer
Decanter
Settled Oil
Acid Sludge

Fig. 16 Batch Process for Acid/Clay Oil Regeneration

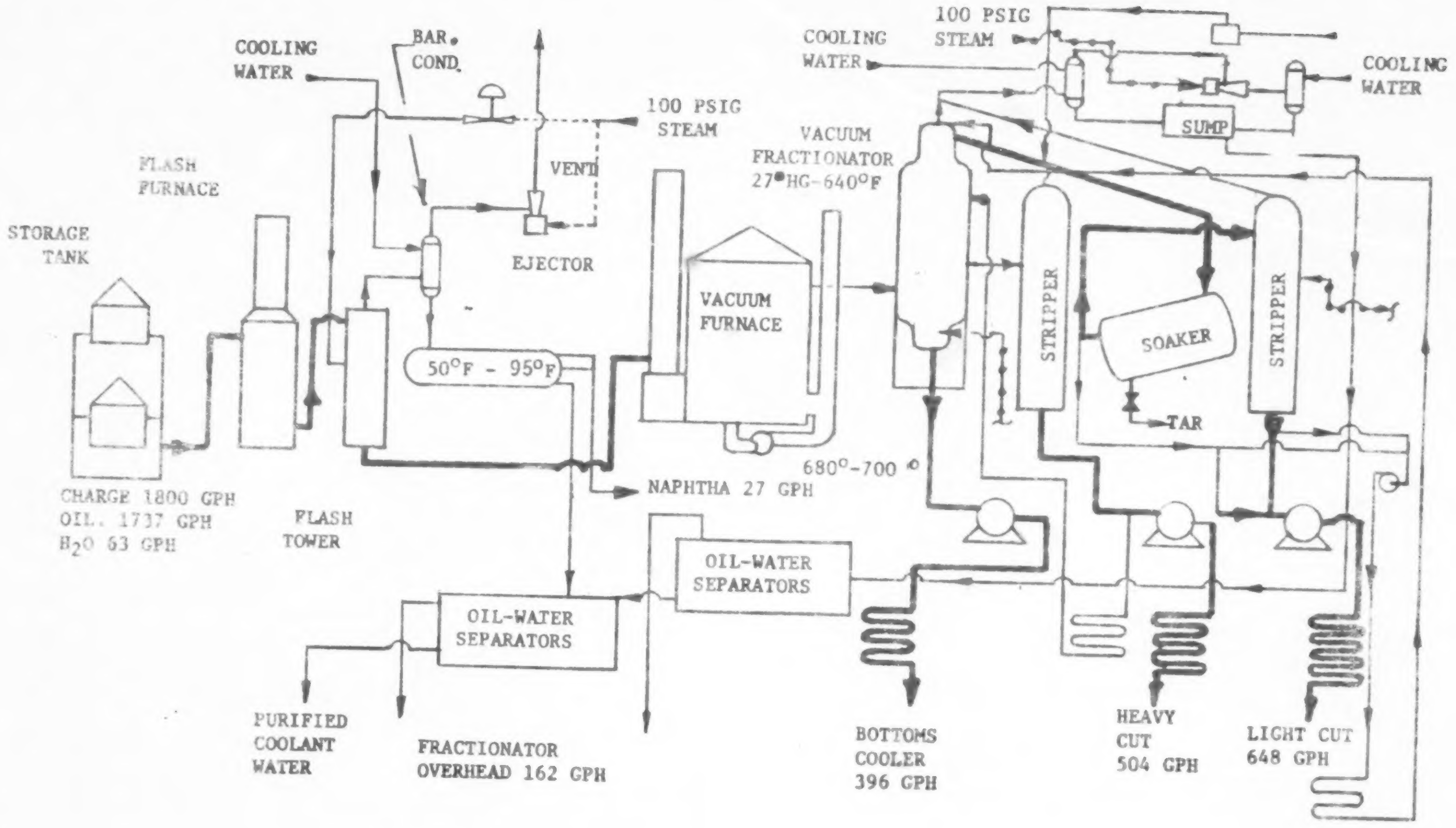

COOLING WATER
BAR. COND.
100 PSIG STEAM
VENT
EJECTOR
FLASH FURNACE
STORAGE TANK
CHARGE 1800 GPH
OIL. 1737 GPH
$H_2O$ 63 GPH
FLASH TOWER
50°F - 95°F
VACUUM FURNACE
NAPHTHA 27 GPH
680°-700 °
VACUUM FRACTIONATOR
27"HG-640°F
100 PSIG STEAM
COOLING WATER
SUMP
COOLING WATER
STRIPPER
SOAKER
STRIPPER
TAR
OIL-WATER SEPARATORS
OIL-WATER SEPARATORS
PURIFIED COOLANT WATER
FRACTIONATOR OVERHEAD 162 GPH
BOTTOMS COOLER 396 GPH
HEAVY CUT 504 GPH
LIGHT CUT 648 GPH

FIGURE 17. RE-REFINING PROCESS FOR WASTE CRANKCASE OILS

(Ref. 38)

bottoms of the flash tower are then fed to a vacuum furnace where the charge is heated up to nearly 700°F and subjected to fractional distillation at relatively low vacuum (27 inches of Hg). In the vacuum distillation tower the feed is separated into a bottoms product, a light overhead product and a middle-heavy cut. The light cut is allowed to soak, that is, age, in a decanting tank for a sufficient period of time to permit the deposition of tarry substances originating due to chemical reaction of precursors. This process uses barometric condensers to maintain the vacuum and thus requires decanting to separate hydrocarbons that accompany the water vapor condensed in these condensers. This function is performed at the oil water separators which separate the overhead light naphthas from the cooling water. This light naphtha may be used as fuel for the plant or used as solvent and similar applications. The light and heavy products may be used for lubricants, rubber oils, fuels and similar applications.

The soaking operation performed in the previously described process has a significance apart from the preparation of the products themselves; in particular, soaking attempts to stabilize the precipitation of tarry bodies and other insoluble materials from the oil. These tarry materials continue to deposit on the bottom of the container upon standing. The tars adhere to the walls of the vessel; the color has been observed to improve slightly on standing.

It appears that various precursors are formed in the lubricating oil during use. These precursors result from the interaction of engine blow-by products with crankcase oil lubricants to form carbonyl and nitrogen oxide compounds in the oil (54), which distill along with various other fractions in the spent lubricating oil and thus continue to exert their effect. Precursor compounds have been shown to continue their sludge formation for many hours after their formation. Their effect can be attenuated by soaking as described above.

The physical/chemical treatment processes for reclaiming used motor oils can be operated on a continuous basis; this is shown in Figure 18 depicting a continuous plant for processing about 5000 gallons of used oil per month. Essentially, this process is similar to a batch process previously described. A larger example of this combined physical/chemical treatment process employing fractional distillation as well as sulfuric acid treatment, activated clay treatment and settling is shown in Figure 19 (7). It should be noted again that this process produces waste water contaminated with oil, an acid sludge waste and an oil-clay waste product which must be disposed of.

Another purely physical process is shown in Figures 20 and 21 reduced to practice in a commercial installation in the United States. The essential processes being carried out here are centrifuging, settling and distillation. This process leads to the production of byproduct gasoline, a carbon-black slurry, four distillation cuts of varying viscosity and composition, and finally a heavy bottoms product. By suitable adjustment of various operating variables, different feedstocks may be used and various products may be produced as a result. This process produces less waste products than the acid-clay process.

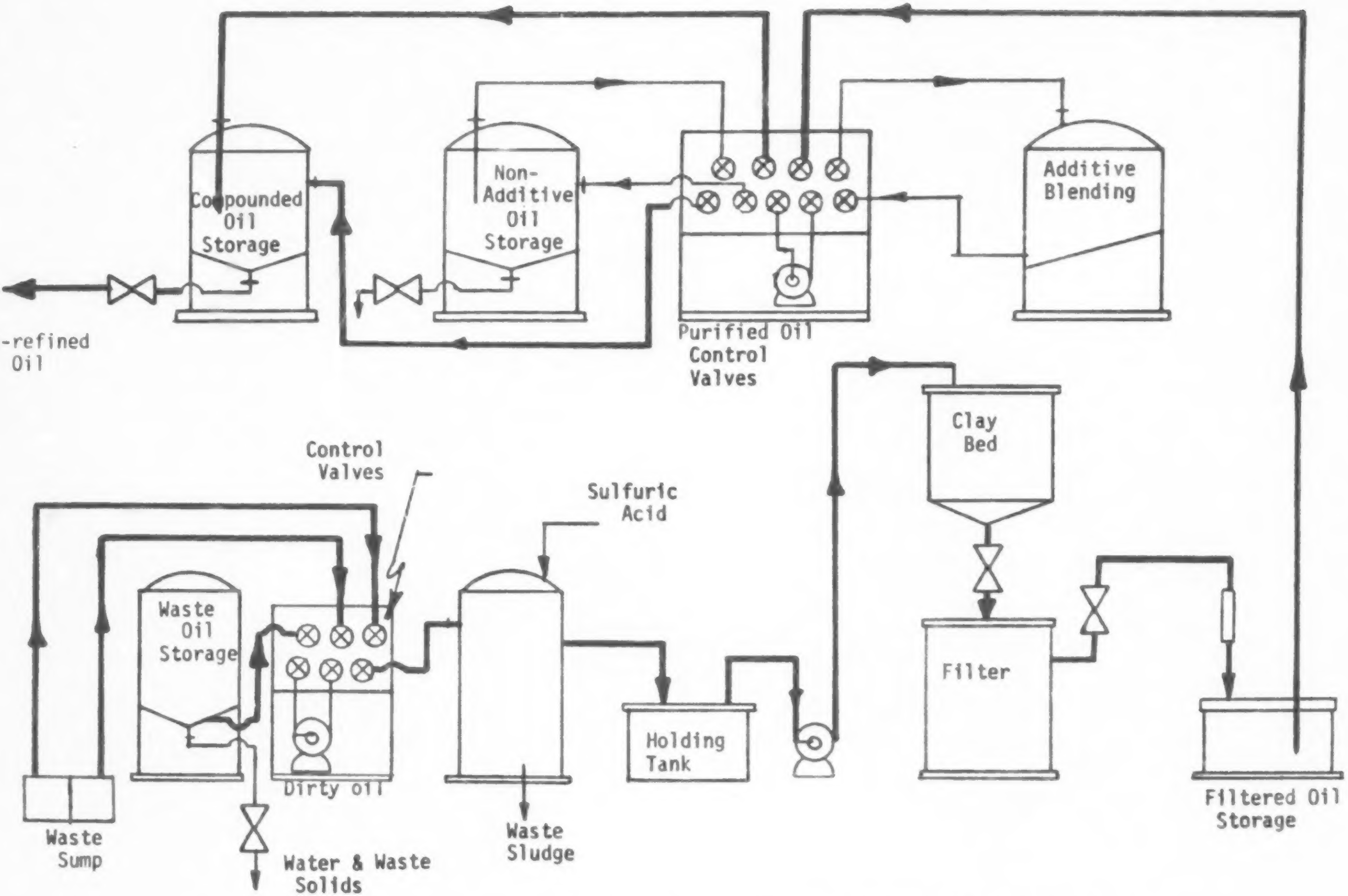

Compounded Oil Storage
Non-Additive Oil Storage
Purified Oil Control Valves
Additive Blending
Re-refined Oil
Clay Bed
Filter
Filtered Oil Storage
Control Valves
Sulfuric Acid
Waste Oil Storage
Dirty oil
Holding Tank
Waste Sump
Water & Waste Solids
Waste Sludge

Fig. 18 Continuous Acid/clay/blending Process for Waste Oil Rerefining (Ref. 7)

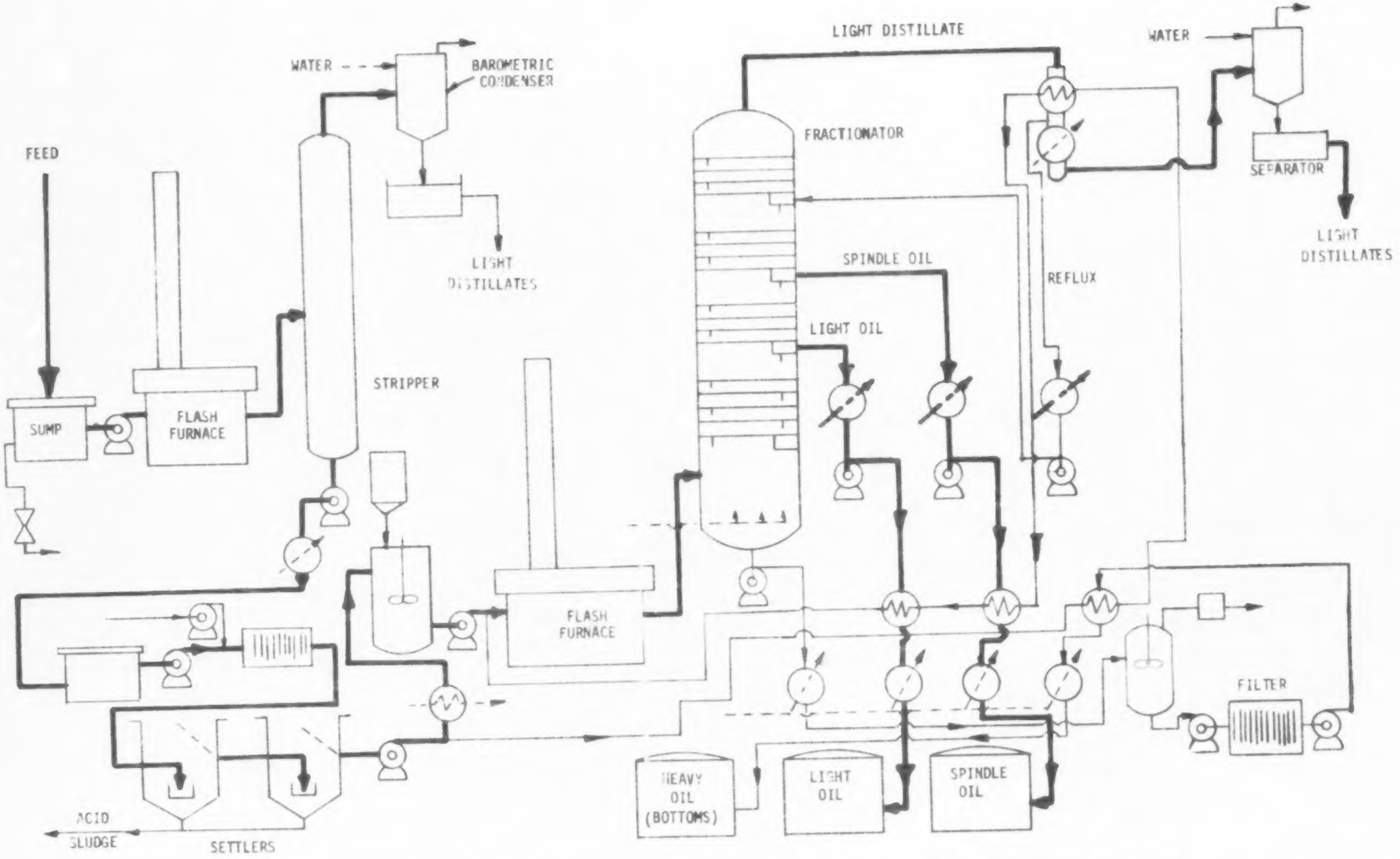

FEED
SUMP
FLASH FURNACE
WATER
BAROMETRIC CONDENSER
LIGHT DISTILLATES
STRIPPER
FLASH FURNACE
ACID SLUDGE
SETTLERS
LIGHT DISTILLATE
FRACTIONATOR
SPINDLE OIL
LIGHT OIL
REFLUX
WATER
SEPARATOR
LIGHT DISTILLATES
FILTER
HEAVY OIL (BOTTOMS)
LIGHT OIL
SPINDLE OIL

Fig. 19. CLAY/ACID/DISTILLATION PROCESS FOR OIL RE-REFINING

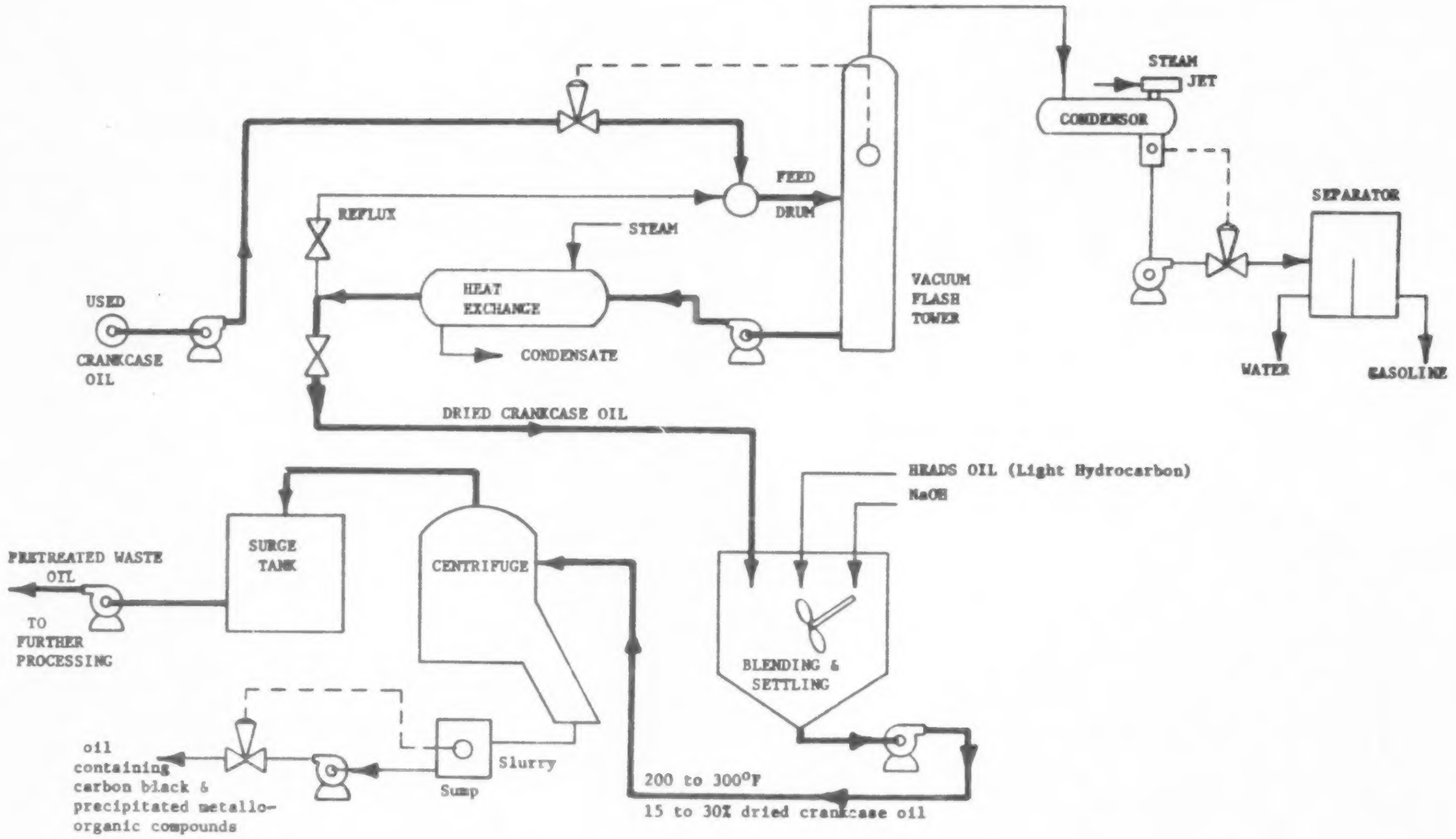

USED
CRANKCASE
OIL
REFLUX
STEAM
HEAT
EXCHANGE
CONDENSATE
FEED
DRUM
VACUUM
FLASH
TOWER
STEAM
JET
CONDENSOR
SEPARATOR
WATER
GASOLINE
DRIED CRANKCASE OIL
HEADS OIL (Light Hydrocarbon)
NaOH
BLENDING &
SETTLING
SURGE
TANK
CENTRIFUGE
PRETREATED WASTE
OIL
TO
FURTHER
PROCESSING
Slurry
Sump
oil
containing
carbon black &
precipitated metallo-
organic compounds
200 to 300°F
15 to 30% dried crankcase oil

FIGURE 20. PROCESS FOR RECOVERING CARBON BLACK AND PETROLEUM PRODUCTS FROM WASTE CRANKCASE OIL. (Ref. 55)

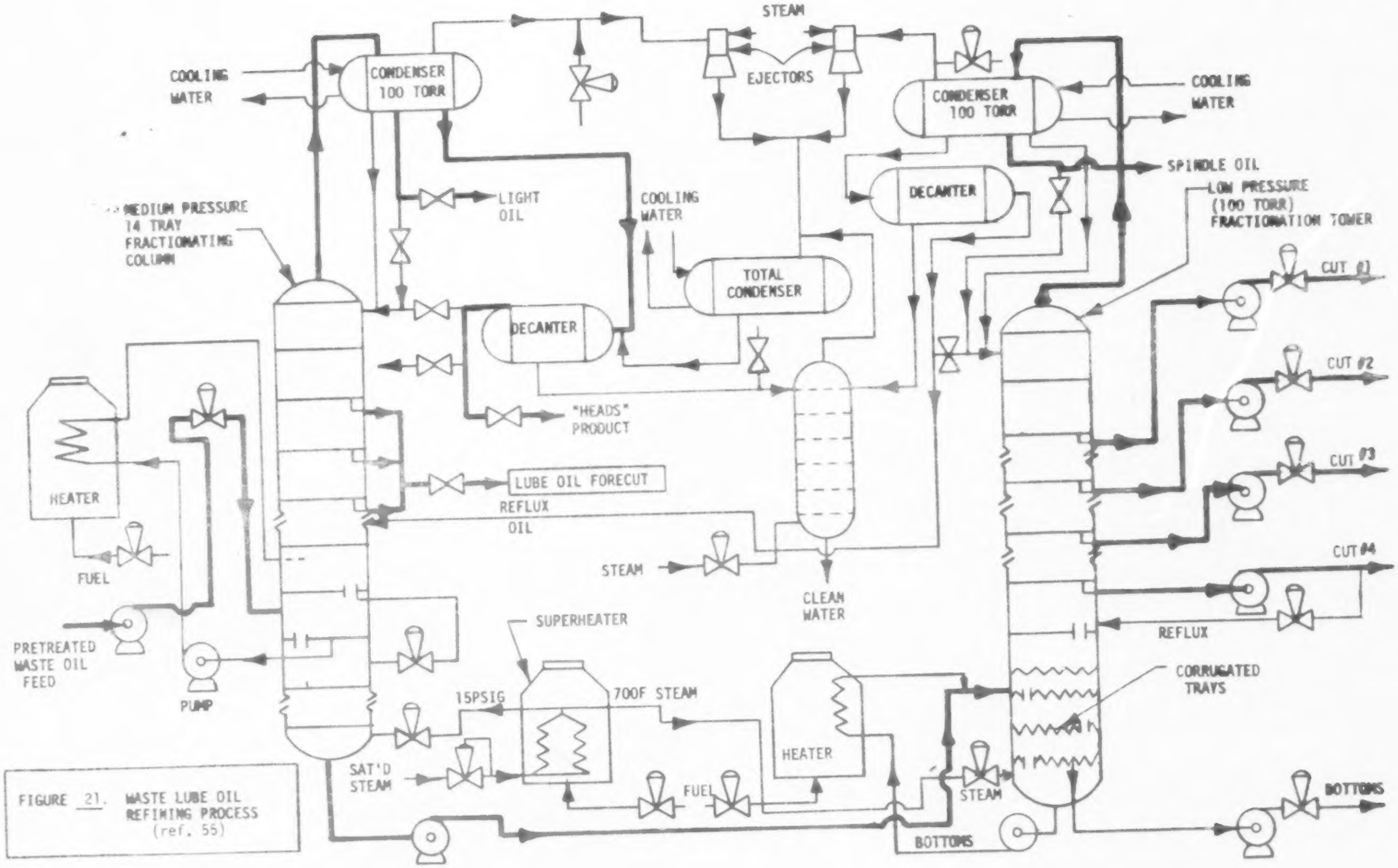

STEAM
EJECTORS
COOLING WATER
CONDENSER 100 TORR
COOLING WATER
CONDENSER 100 TORR
SPINDLE OIL
LOW PRESSURE (100 TORR) FRACTIONATION TOWER
MEDIUM PRESSURE 14 TRAY FRACTIONATING COLUMN
LIGHT OIL
COOLING WATER
DECANTER
TOTAL CONDENSER
DECANTER
"HEADS" PRODUCT
LUBE OIL FORECUT
REFLUX OIL
CUT #1
CUT #2
CUT #3
CUT #4
REFLUX
HEATER
FUEL
PRETREATED WASTE OIL FEED
PUMP
STEAM
CLEAN WATER
SUPERHEATER
15PSIG
700F STEAM
SAT'D STEAM
FUEL
HEATER
CORRUGATED TRAYS
STEAM
BOTTOMS
BOTTOMS

FIGURE 21. WASTE LUBE OIL REFINING PROCESS (ref. 55)

A partial purification process for restoring used diesel oil lubricants has been described by Graves (56). In this process a small amount of phenyl alkyl amine such as N-phenyldiethanolamine is added to the waste diesel lubricant to flocculate suspended impurities so that they may be separated by simple gravity settling. An example is cited as follows: a waste diesel lube is heated to 220-330°F to drive off volatile impurities; subsequently 0.5 percent of the amine is added and the mixture stirred, allowed to settle for two weeks and the supernatant clear oil is decanted. A yield of 95 percent is claimed and the oil is stated to be "suitable for reuse as a general machine oil". The applicability of this process for reprocessing modern used motor oils both from diesel or gasoline engine service is not known. In a later process patented by Mitacek (57) a similar precipitating process using hydrazine at a concentration of 5 to 10 percent by volume added to the waste automotive crankcase oil is used to precipitate carbon, metal particles and other suspended impurities. The process is carried out over the range of 50 to 150°F. Products produced by this process were described in Section VII, Table 23.

The popularity of the acid-clay refining process for waste crankcase oil led to its extensive use in many locations. Depending on the feedstock charged in the process, the acid-clay method can yield from 75 to 85 percent of the original oil; however, this is accompanied by large amounts of waste acid and clay sludge. This sludge has been studied (58) and attempts made to process it for the recovery of lube oil, polymers, acid values and other possibly valuable materials. Figure 22 describes this fractionation process for an acid sludge resulting from waste crankcase oil refining. It should be noted that this is an experimental process but does indicate the potentiality for recovering the waste values in the sludge thereby enhancing the acid-clay process and possibly reducing overall process costs.

All the processes described thus far are directed, essentially, toward treating crankcase oils from diesel and gasoline engines. Frequently, the charge stocks to these processes have appreciable quantities of industrial lubricants and other oily wastes. If the waste oil is predominantly industrial lube oil, it is subjected to a different treatment process by the re-refiner. However, many industrial establishments practice in-house purification of lubricating oils for various types of operations, particularly turbine oil, transformer oil and metal-working lubricant applications.

For example, filtration using diatomaceous earth and tubular filters has been used for purification and recirculation of oil resulting from the manufacture of rolled aluminum products (59). An 80 sq. ft. tubular element filter is precoated with 20 lbs. of diatomaceous earth filter aid prior to pumping in impure oil for filtration. Subsequently, the oil to be purified is mixed with a small amount of filter aid (termed "body feed") as it is pumped into the filter for purification. Approximately 80 lbs. of waste filter aid cake consisting of dark oil, contaminant solvents and the diatomaceous earth are produced during each 24-hour filter cycle period. This particular filter operates at a rate of 240 gallons per minute at a temperature of 130 to 159°F. The product produced by this filtration process yielded an ash of 0.002 percent.

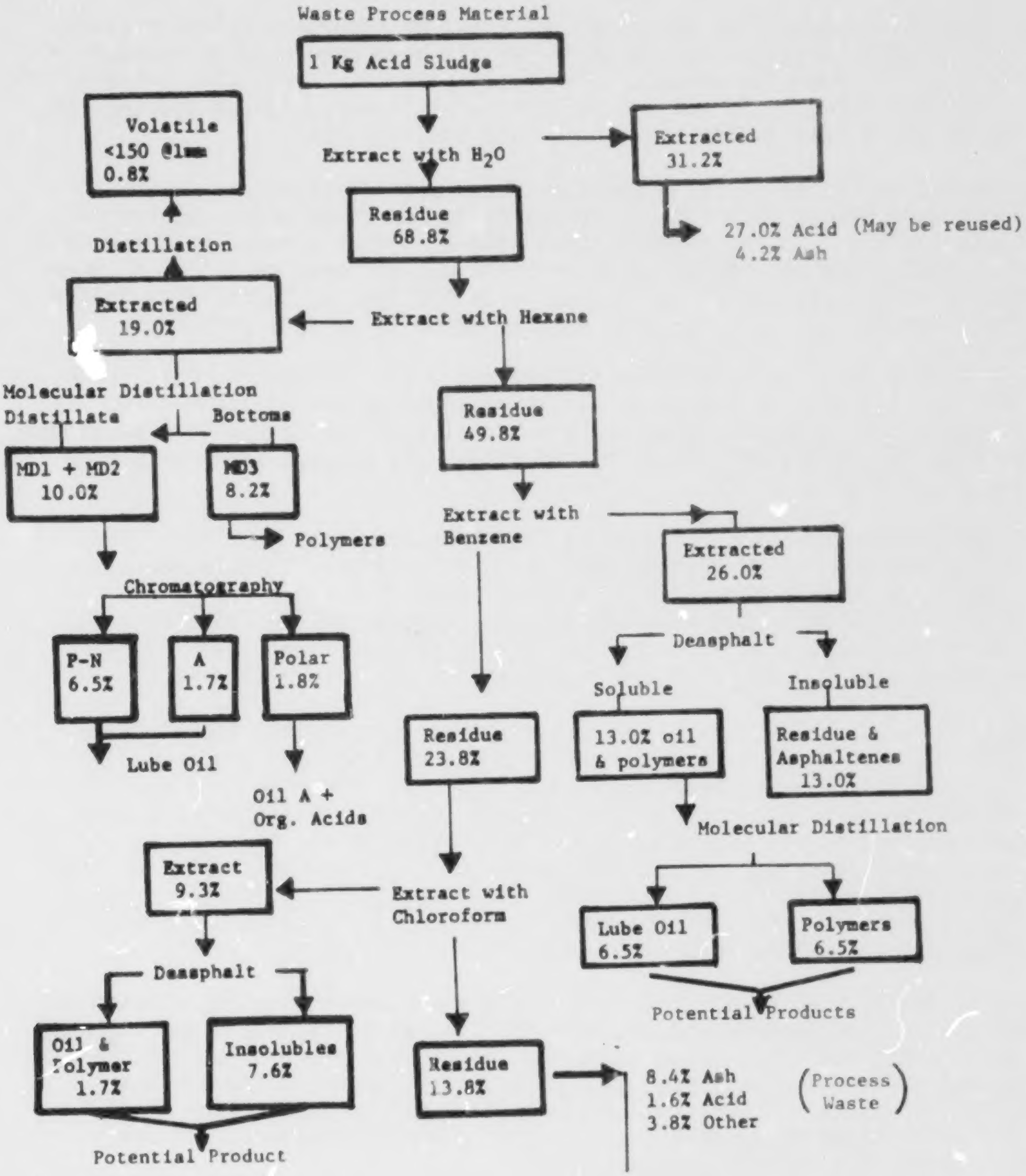

Waste Process Material
1 Kg Acid Sludge
Volatile
<150 @1mm
0.8%
Extract with $H_2O$
Extracted
31.2%
Residue
68.8%
27.0% Acid (May be reused)
4.2% Ash
Distillation
Extracted
19.0%
Extract with Hexane
Molecular Distillation
Distillate
Bottoms
Residue
49.8%
MD1 + MD2
10.0%
MD3
8.2%
Polymers
Extract with
Benzene
Extracted
26.0%
Chromatography
Deasphalt
P-N
6.5%
A
1.7%
Polar
1.8%
Soluble
Insoluble
Residue
23.8%
13.0% oil
& polymers
Residue &
Asphaltenes
13.0%
Lube Oil
Oil A +
Org. Acids
Molecular Distillation
Extract
9.3%
Extract with
Chloroform
Lube Oil
6.5%
Polymers
6.5%
Deasphalt
Potential Products
Oil &
Polymer
1.7%
Insolubles
7.6%
Residue
13.8%
8.4% Ash
1.6% Acid
3.8% Other
Process
Waste
Potential Product

FIGURE 22. FRACTIONATION OF ACID SLUDGE FROM WASTE CRANKCASE OIL RE-REFINING. (Ref. 58)

In a similar industrial operation, mixtures of adsorbant Fuller's earth together with diatomaceous earth filter aid have been used to recover rolling oils from the production of aluminum foil. Typically, a 200 sq. ft. filter operating at 50 gallons per minute will produce about 150 lbs. per day of waste cake solids bearing the oil impurity (59).

A number of oil re-refining operators have used diatomaceous earth filtration either on a rotary precoat filter or fixed media tubular or plate filters. In one example cited (59) all stock treated by the acid-clay method and at a temperature of 210°F was filtered on a 6' x 6' Dorr-Oliver rotary precoat filter charged with 400 lbs. of Celite #503 filter aid. The oil was filtered at a rate of 20 to 30 gallons per minute.

In another operation involving filtration, a die lubricating oil "Turbo-500" was filtered to remove particles of aluminum and aluminum-oxide produced during the stamping and drawing of aluminum cans. This particular process (59) operated with 8 lbs. of filter aid precoat along with a 41 sq. ft. filter.

Waste turbine oils also refined by clay bleaching have been purified further by the use of diatomaceous earth filtration. In this operation, filter aid is used to precoat plate and frame filter presses or tubular filters after which the clay-bearing used turbine oil is filtered to remove suspended organic contaminants and the bleaching clay. Similarly, used transformer oils have been reclaimed by the same method (59).

Cutting oils for machining operations have been reclaimed industrially for many years. In a typical operation the cutting oils are separated from all the chips by means of a chip extractor, and then permitted to settle in a vertical storage tank. Subsequently, the settled oil without heavy solids is heated to about 180°F and held at that temperature for several hours to permit settling out of the finer particles and then purified on a centrifugal separator. The clarified oil is then cooled and returned to use after the addition of disinfectants and additives necessary to restore the original condition.

In a similar application the oil is separated from the chips, allowed to settle at room temperature and then is mixed with filter aid and filtered on a horizontal plate filter equipped with filter paper. The oil is passed through a magnetic filter to remove any magnetic iron in the colloidal state. The reclaimed lubricating oil is used either directly for lubricating purposes or, by blending with disinfectants and oil additives, for cutting purposes (60).

Another important industrial operation is steel rolling which requires large quantities of lubricants for both the operation of machinery and lubrication of the steel strip itself. In hot strip mills, waste oils frequently are recovered by settling followed by skimming as shown in Figure 23. The treated waste oil can be used as fuel in mill operation.

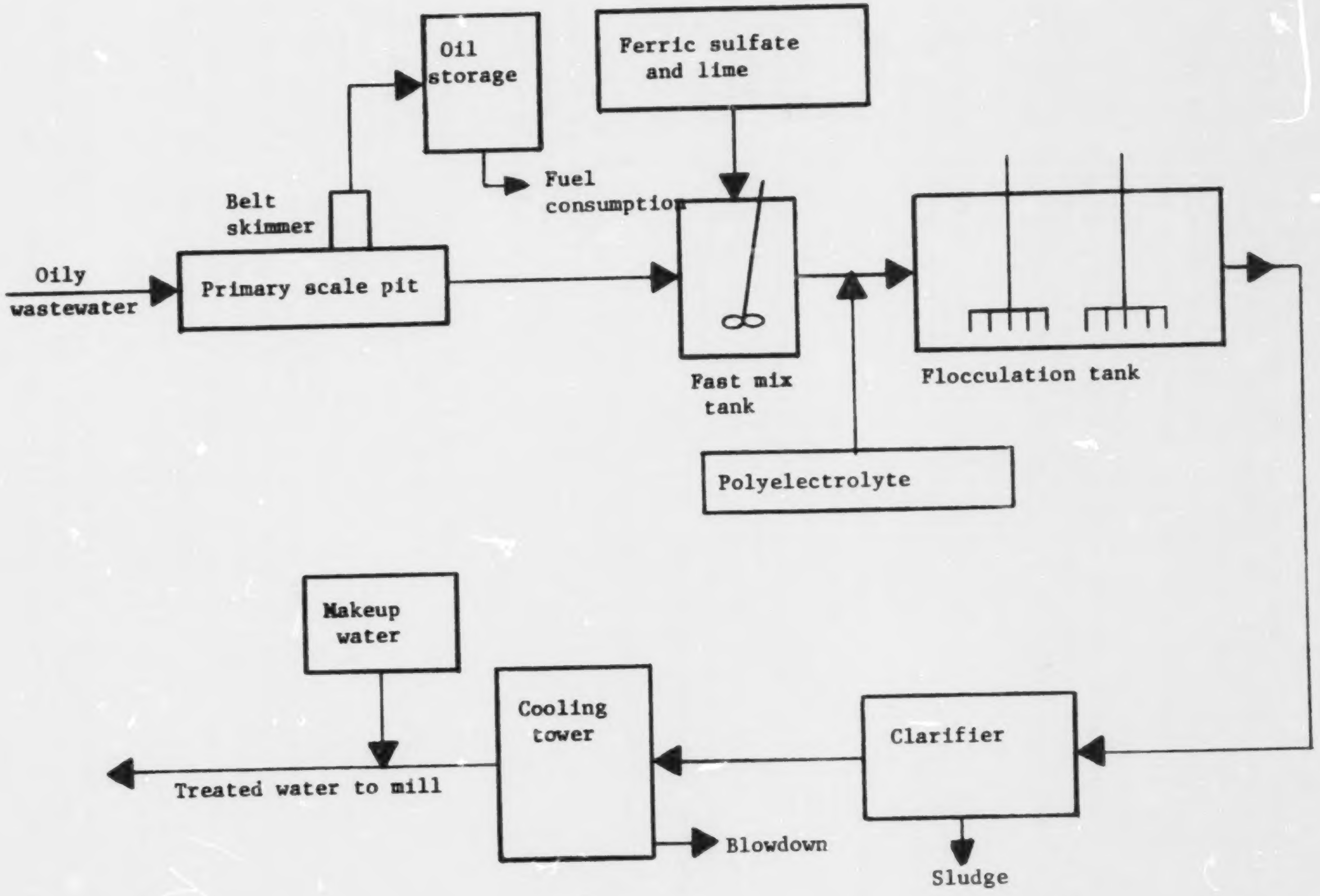

Oily wastewater
Primary scale pit
Belt skimmer
Oil storage
Fuel consumption
Ferric sulfate and lime
Fast mix tank
Polyelectrolyte
Flocculation tank
Clarifier
Sludge
Cooling tower
Blowdown
Makeup water
Treated water to mill

FIGURE 22 RECLAMATION OF STEEL HOT-STRIP MILL WASTE LUBRICANT OILS. (Ref. 23)

Cold reduction steel mills use large quantities of soluble oil coolants during the rolling operation; Figure 24 illustrates this system. In the operation shown, a small quantity of oil is removed from the main oil cellar for purification along with the oil and solids picked up by vacuum filtration operating on a side stream circuit from the main oil cellar. Since recovered oil consists primarily of saponified soluble oils, it may be either recycled to the oil cellar along with suitable additives or it may be used for external uses such as the manufacture of soaps.

Another large user of soluble oils are aluminum rolling mills. During operation these mills produce oily wastes which may be recovered both as free oil and as waste oily sludges (23) as shown in Figure 25. Recovered free oil may be reused while the waste oily sludges are generally incinerated.

Another important industrial oil purification process involves treating turbine lubricating oils. As discussed earlier, large quantities of oils are circulated in modern turbines for the purpose of lubricating and cooling vital rotating surfaces. Such installations usually have large in-plant purification systems. Figure 26 illustrates such a system. The major separation process here is settling and centrifugal separation to remove particles and water. Unprocessable dirty oil resulting from turbine repair or installation procedures frequently results because of flushing operations. In this case, a large one-time batch of dirty waste turbine oil must be disposed of since such material is not handled by the purification system shown in Figure 26. Instead, it is removed for treatment and reclamation or burning by another facility.

Engine manufacturing plants also use large quantities of soluble oil for machining operations. In addition, other lubricants such as hydraulic oil and honing oil are found in these operations. Together these lubricants contribute to the formation of waste oils which can be recovered and reused as soluble oils for further machining. Figure 27 illustrates the manufacture of soluble oils from waste industrial oils (62).

Another source of waste oil may be found in the operation of transformers. These oils may be purified and returned to the transformer for use or, if desired, the oil may be removed from the transformer and replaced with new oil. The waste oil is removed to a facility for purification and reuse in another application. Figure 28A illustrates purification of transformer oil (63) to remove acid, sludge, alcohols, aldehydes, other decay products and water. The major process control parameters are the interfacial tension of the oil (dynes/cm with respect to distilled water) and the acid number (expressed as milligrams of potassium hydroxide per gram of oil). Strictly speaking, this process is not completely a physical process since Fuller's earth is used as an adsorbent; however, the primary processes are filtration coupled with vacuum distillation. The effect of recirculation through the purification system is shown in Figure 28B.

Worrel describes a process employing Fuller's earth as an adsorbent for reconditioning oil (64). In this operation, the turbine oil was purified after 89,212 hours of operation by filtration on a commercial Fuller's

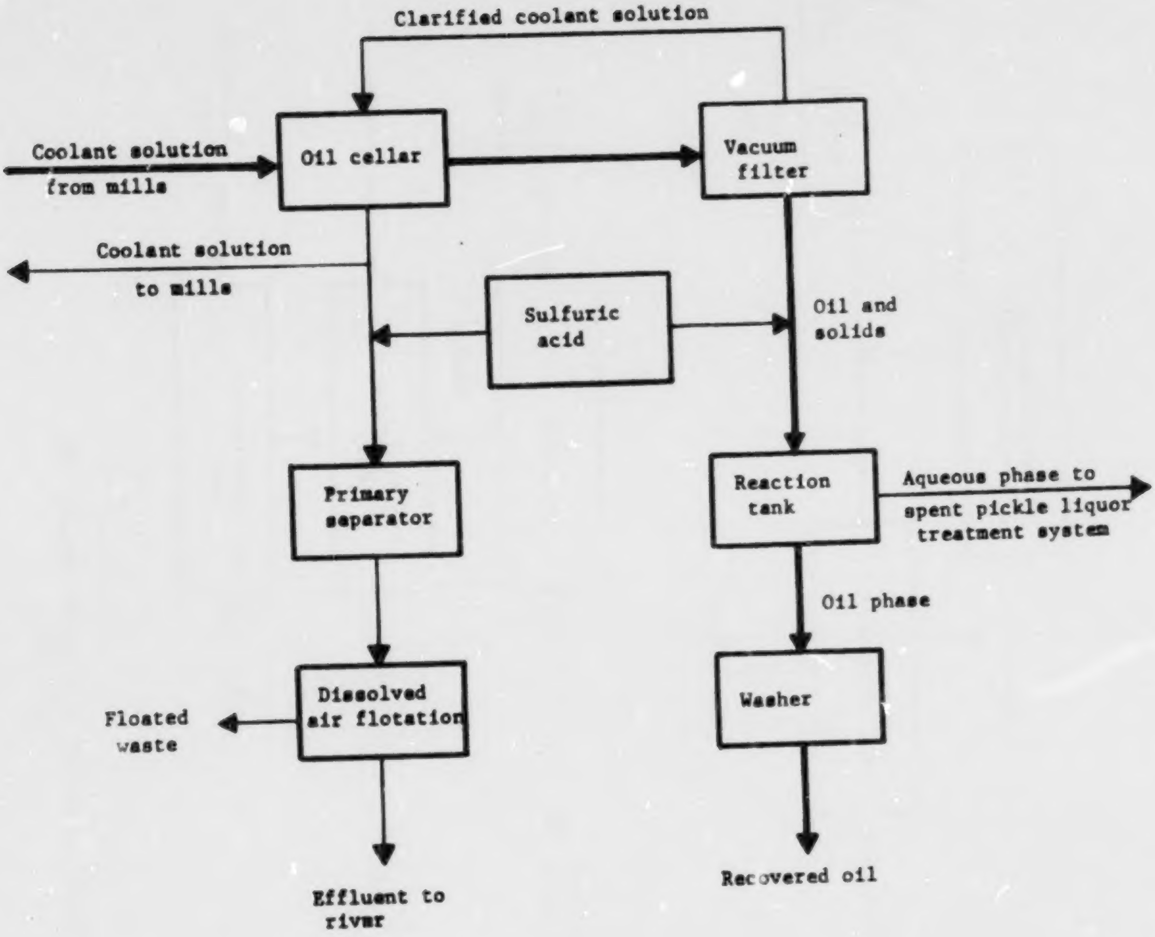

Clarified coolant solution
Coolant solution from mills
Oil cellar
Vacuum filter
Coolant solution to mills
Sulfuric acid
Oil and solids
Primary separator
Reaction tank
Aqueous phase to spent pickle liquor treatment system
Oil phase
Dissolved air flotation
Floated waste
Washer
Effluent to river
Recovered oil

FIGURE 24. OIL RECLAMATION SYSTEM FOR COLD REDUCTION STEEL MILL. (Ref. 23)

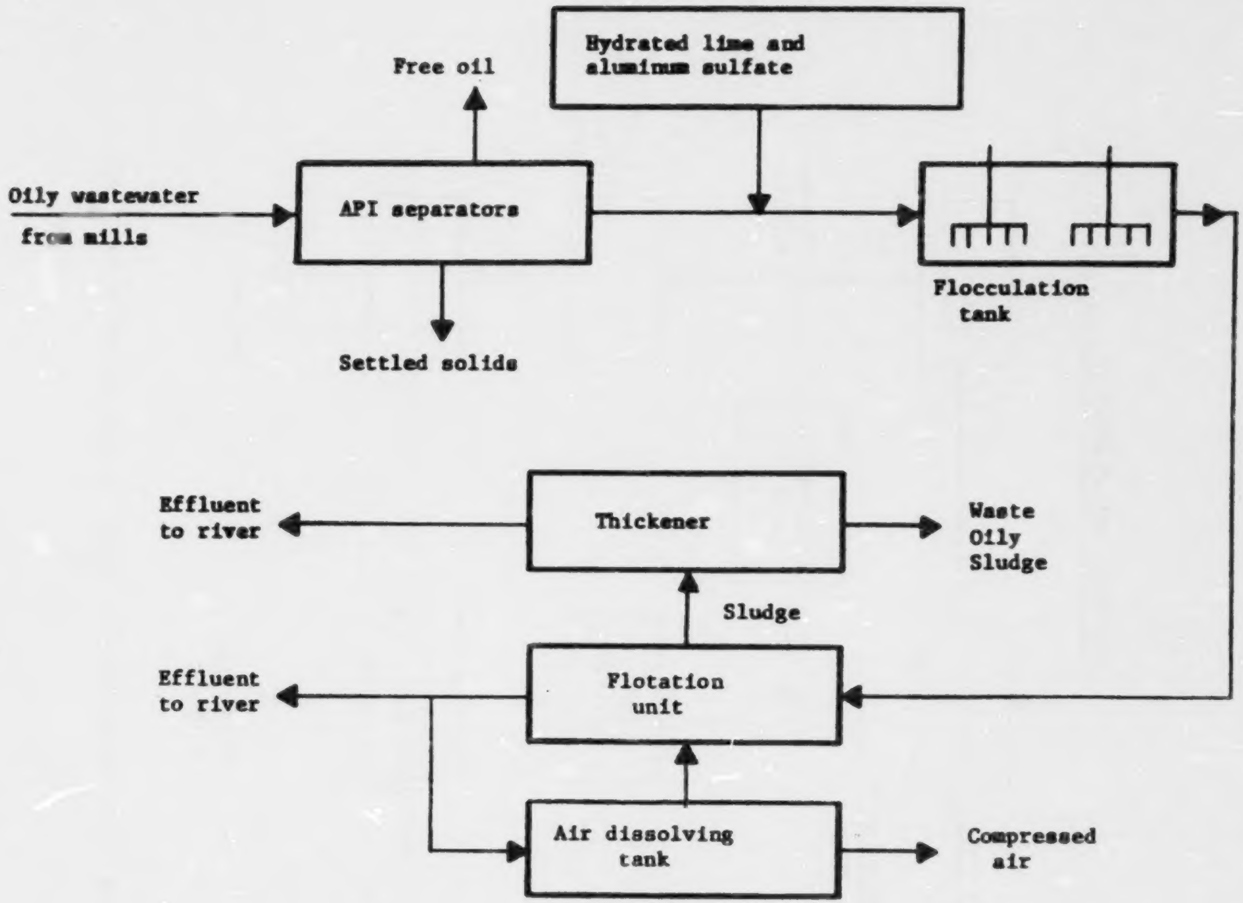

Oily wastewater
from mills
API separators
Free oil
Settled solids
Hydrated lime and
aluminum sulfate
Flocculation
tank
Effluent
to river
Thickener
Waste
Oily
Sludge
Sludge
Effluent
to river
Flotation
unit
Air dissolving
tank
Compressed
air

FIGURE 25 . LUBRICANT RECOVERY IN ALUMINUM ROLLING MILL.
(Ref. 23)

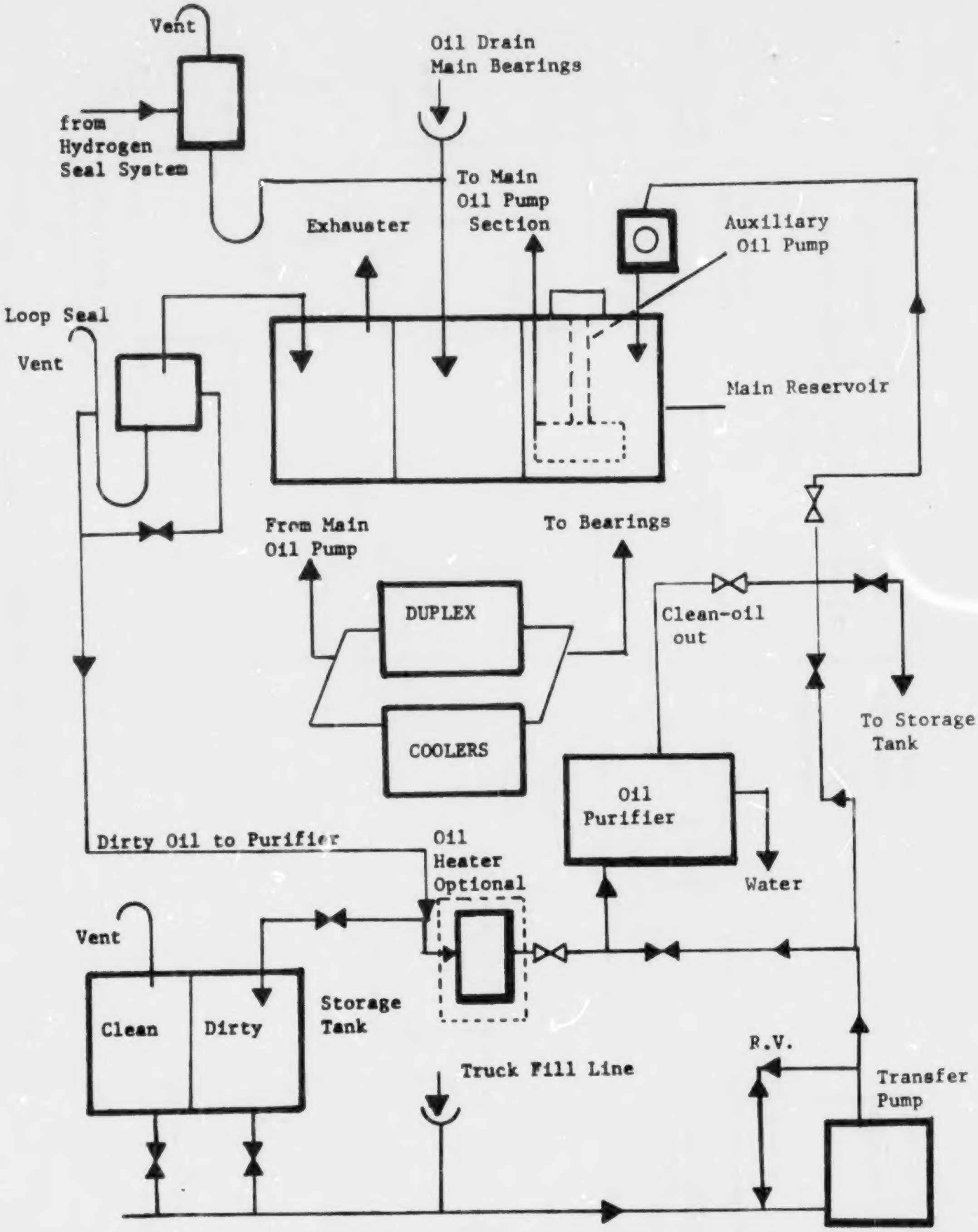

Vent
from Hydrogen Seal System
Oil Drain Main Bearings
To Main Oil Pump Section
Exhauster
Auxiliary Oil Pump
Loop Seal
Vent
Main Reservoir
From Main Oil Pump
To Bearings
DUPLEX
COOLERS
Clean-oil out
To Storage Tank
Oil Purifier
Water
Dirty Oil to Purifier
Oil Heater Optional
Vent
Clean
Dirty
Storage Tank
Truck Fill Line
R.V.
Transfer Pump

FIGURE 26. TURBINE LUBRICATING OIL PURIFICATION SYSTEM (Ref. 61)

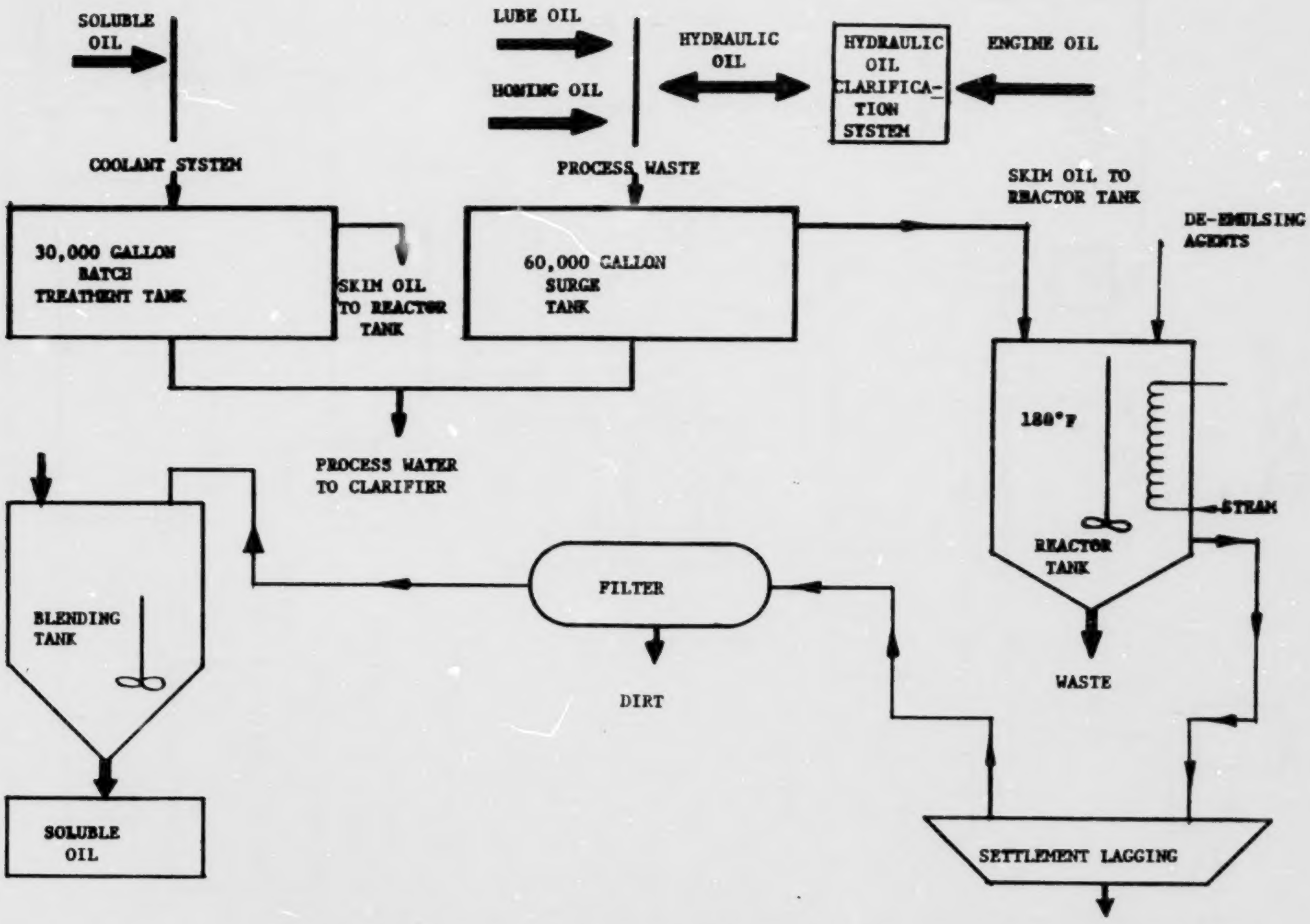
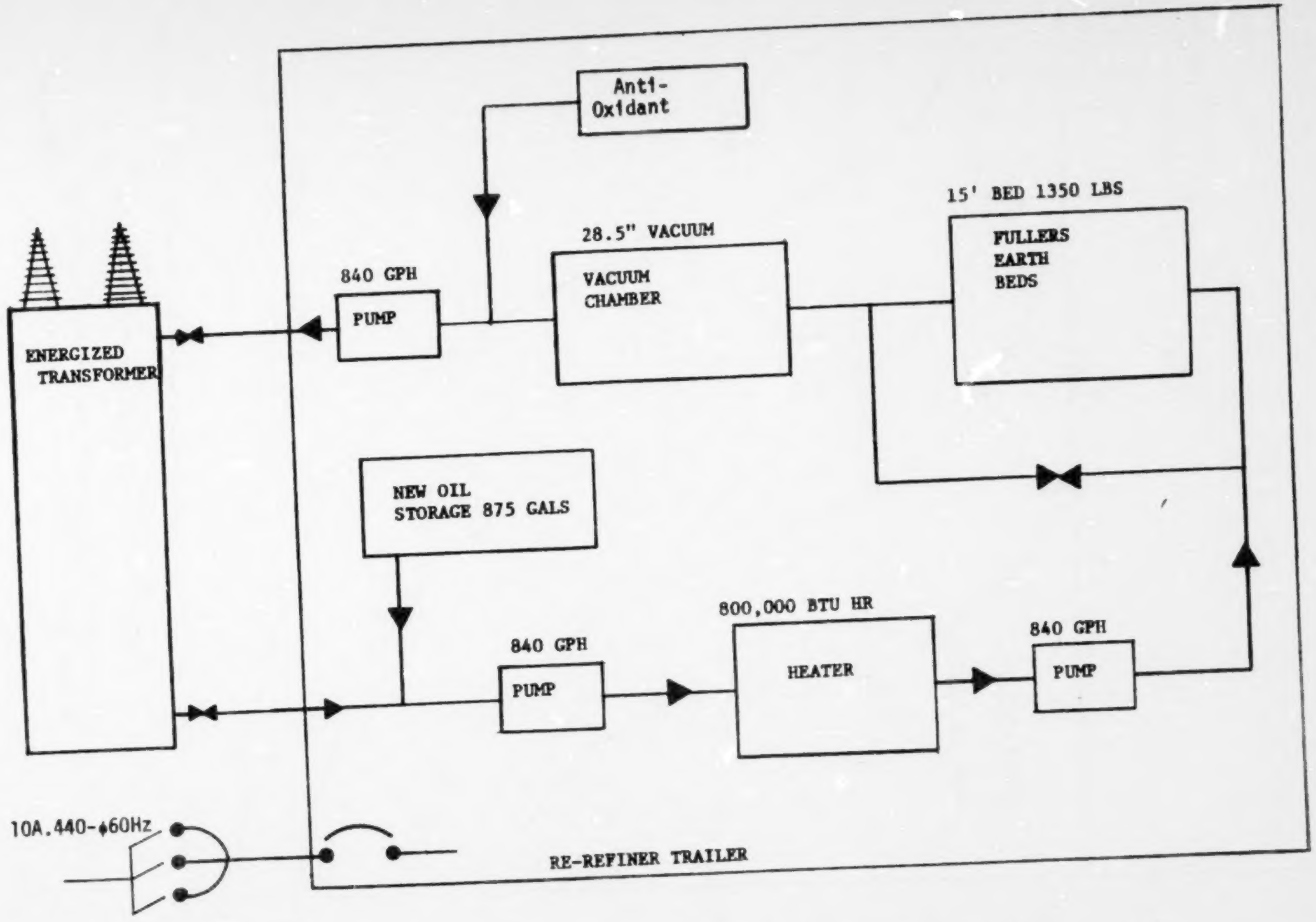

SOLUBLE OIL
COOLANT SYSTEM
LUBE OIL
HONING OIL
HYDRAULIC OIL
HYDRAULIC OIL CLARIFICATION SYSTEM
ENGINE OIL
PROCESS WASTE
30,000 GALLON BATCH TREATMENT TANK
SKIM OIL TO REACTOR TANK
60,000 GALLON SURGE TANK
SKIM OIL TO REACTOR TANK
DE-EMULSING AGENTS
180°F
STEAM
REACTOR TANK
WASTE
PROCESS WATER TO CLARIFIER
BLENDING TANK
FILTER
DIRT
SOLUBLE OIL
SETTLEMENT LAGGING
DIRT & WATER

FIGURE 27. MANUFACTURE OF SOLUBLE OIL FROM WASTE INDUSTRIAL OILS. (Ref. 62)



Anti-
Oxidant
28.5" VACUUM
VACUUM
CHAMBER
15' BED 1350 LBS
FULLERS
EARTH
BEDS
840 GPH
PUMP
ENERGIZED
TRANSFORMER
NEW OIL
STORAGE 875 GALS
840 GPH
PUMP
800,000 BTU HR
HEATER
840 GPH
PUMP
10A.440-ϕ60Hz
RE-REFINER TRAILER

FIGURE 28-A. TRANSFORMER OIL PURIFICATION (Ref. 63)

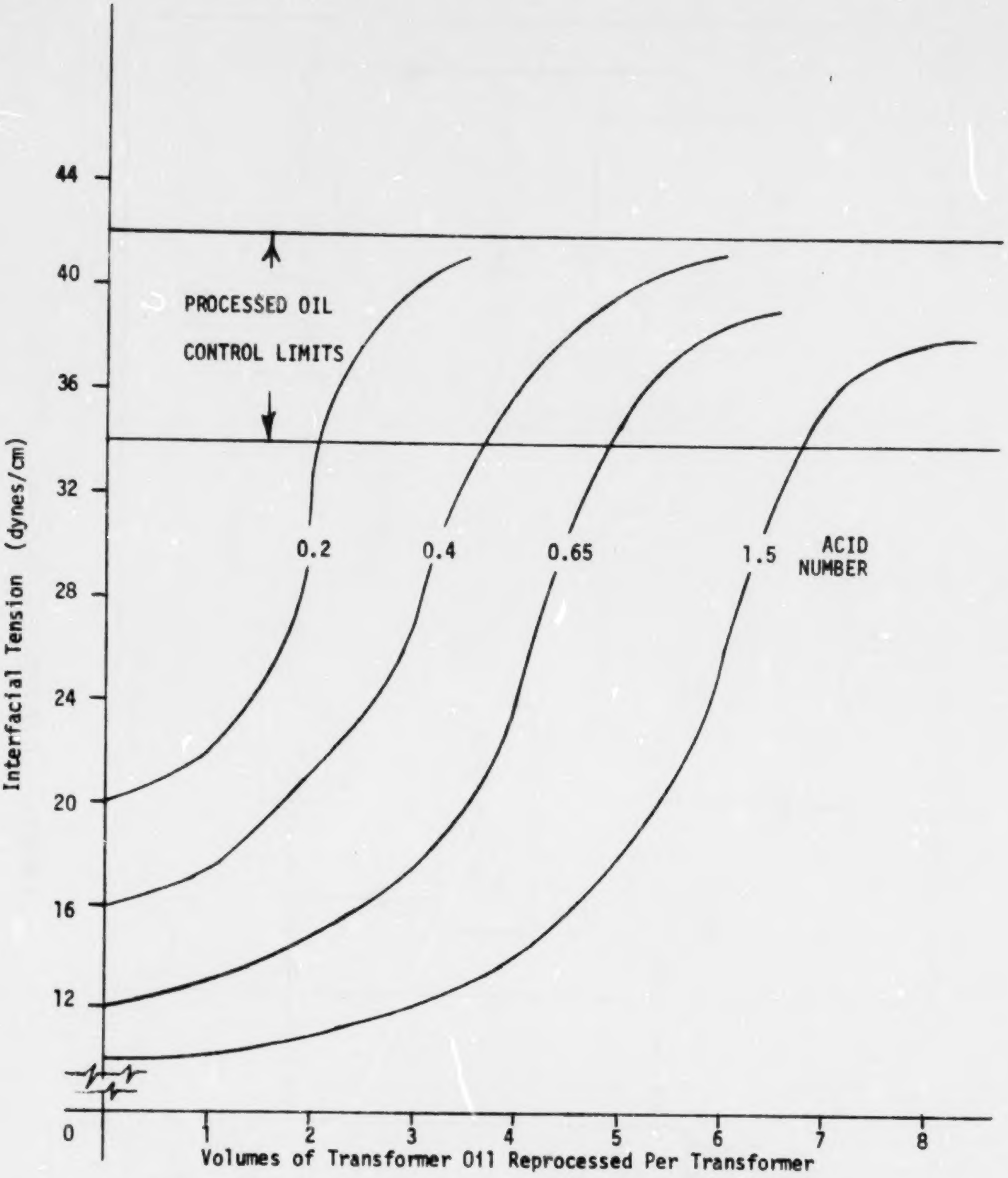


Fig. 28-B. Relationship Between Acid Number and Interfacial Tension During Transformer Oil Purification (Ref. 63)

earth filter containing 90 lbs. of Fuller's earth followed by centrifugal clarification; subsequently, the purified oil was returned to the turbine by means of a bypass arrangement. Again, the major control parameter was interfacial tension which was maintained at 50 dynes per centimeter on the purified oil. Fuller's earth was used at a rate of 1/2 pound per gallon of oil and was changed every 24 hours. In order to maintain the proper water shedding, oxidation and corrosion inhibition characteristics, the repurified oil was re-inhibited by the addition of an oil solution containing these additives.

Another source of oily waste is cleaning of tank trucks which results in oily wastewater. The wastewater may be separated by appropriate treatment to produce an oily waste scum which may be recovered and disposed of by incineration. Figure 29 illustrates the basic steps in this process (23).

Straight cutting oil frequently contains volatile ingredients including solvents and moisture. These impurities can be removed by vacuum distillation which effectively purifies the oil and renders it suitable for reuse or further processing (65). Figure 30 illustrates a small package system for in-plant recovery of waste cutting oil and solvent. The vacuum still is operated at a pressure just low enough to remove volatile materials.

When these are removed, the liquid in the evaporator sump is pumped either to another purification system, say, clay treatment, or is sent to storage for reuse.

A large number of chemical processes have been applied to both lube oil manufacture and waste industrial and lube oil recovery. The preceding material discussed primarily physical processes; some chemical processing steps also were included in order to present an integrated picture of the process. An important aspect of both chemical and physical processing is the waste produced by the process itself; this is particularly true in the case of the acid-clay treatment systems (discussed more fully in Section XV) which employ distillation, settling and filtration as well. One of the early important chemical treatment steps involving adsorptive purification of waste oils is clay treatment. Figure 31 illustrates this important process. Many different types of clays have been tested for use in oil purification; frequently this is carried out at elevated temperatures and in a state of agitation to cause intimate contact between the oil to be purified and the adsorbent clay. These early processes gave relatively good results and high yields of recovered oil at that time. Impurities removed include dissolved sludge, the less volatile acids, asphaltenes, polymerization products, color bodies, soap, certain types of unexpended additives, metal particles, free carbon and dirt; and because of the elevated temperature of some of the processes, volatile acids, aldehydes and other oxidation products as well. The oil produced by this purification process was considered to be of a quality suitable for direct reuse. However, the changing composition of motor oils has made the recovery of used internal combustion engine lubricants more difficult because of the increased amounts of additives and the change in the type of additives.

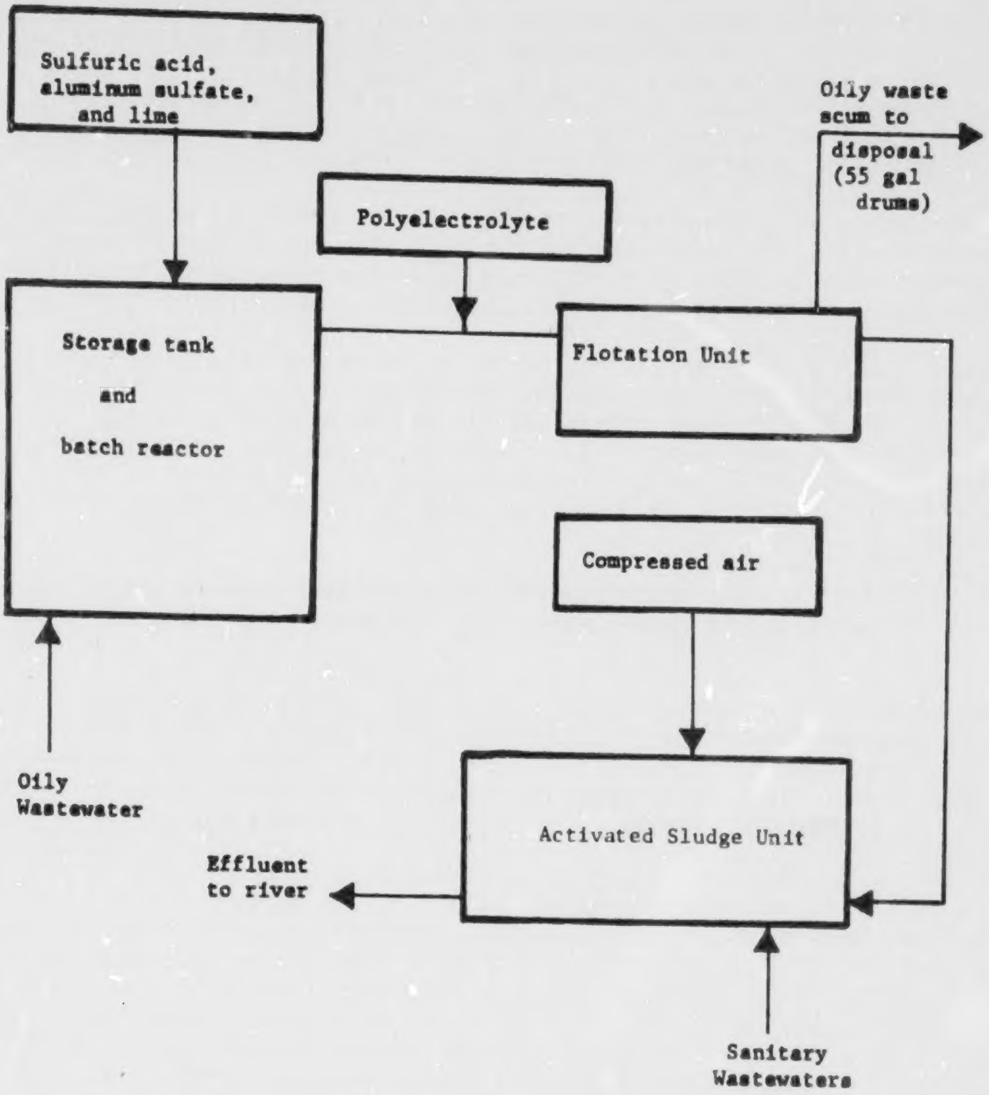
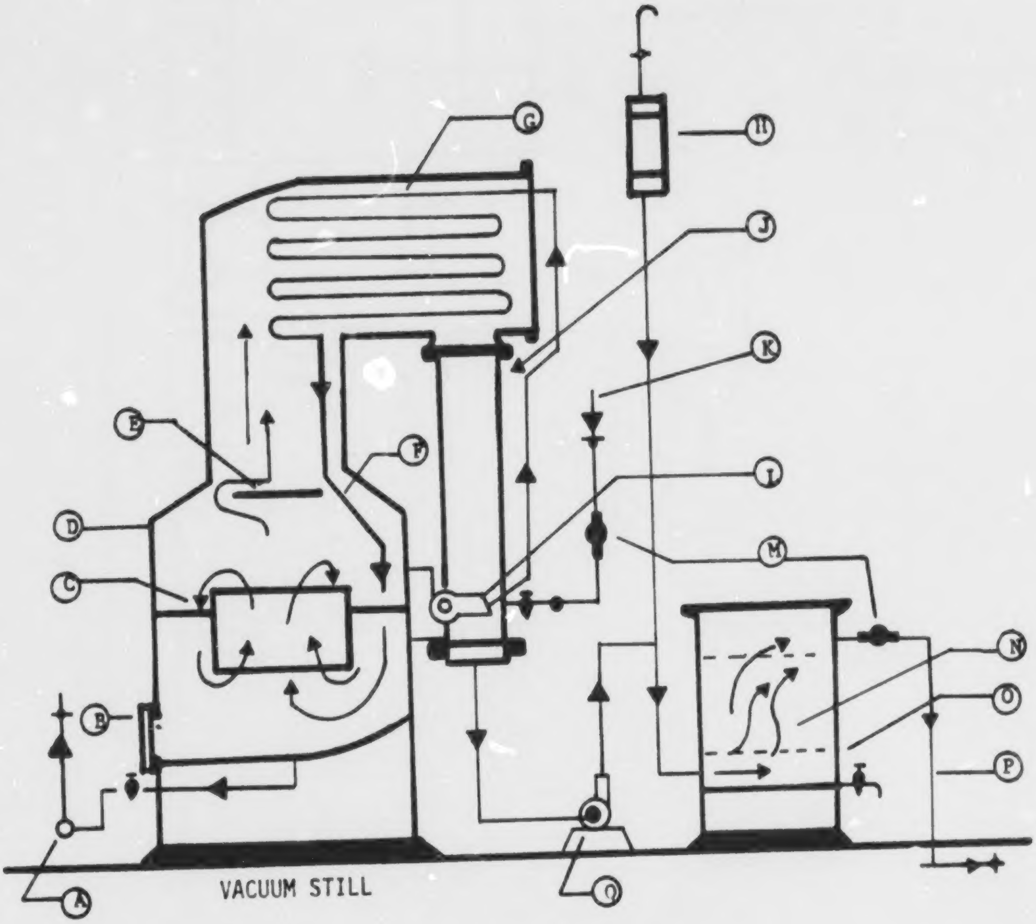

Sulfuric acid,
aluminum sulfate,
and lime
Polyelectrolyte
Oily waste
scum to
disposal
(55 gal
drums)
Storage tank
and
batch reactor
Flotation Unit
Compressed air
Oily
Wastewater
Activated Sludge Unit
Effluent
to river
Sanitary
Wastewaters

FIGURE 29 . TANK TRUCK CLEANING WASTE TREATMENT. (Ref. 23)



A - Hot Residue Pump
B - Access Port
C - Steam Calandria Unit
D - Vaporizing Chamber
E - Vapor Baffle
F - Feed Pipe
G - Heat Exchanger
H - Vacuum Pump
Vent Baffle

J - Condenser
K - Dirty Solvent Line
L - Solvent Feed Regulator
M - Sight Flows
N - Moisture Adsorption Bed
O - Moisture Filter
P - Distilled Solvent Line
Q - Wet Vacuum Pump

FIGURE 30. VACUUM DISTILLATION OF WASTE CUTTING OIL (Ref. 65)

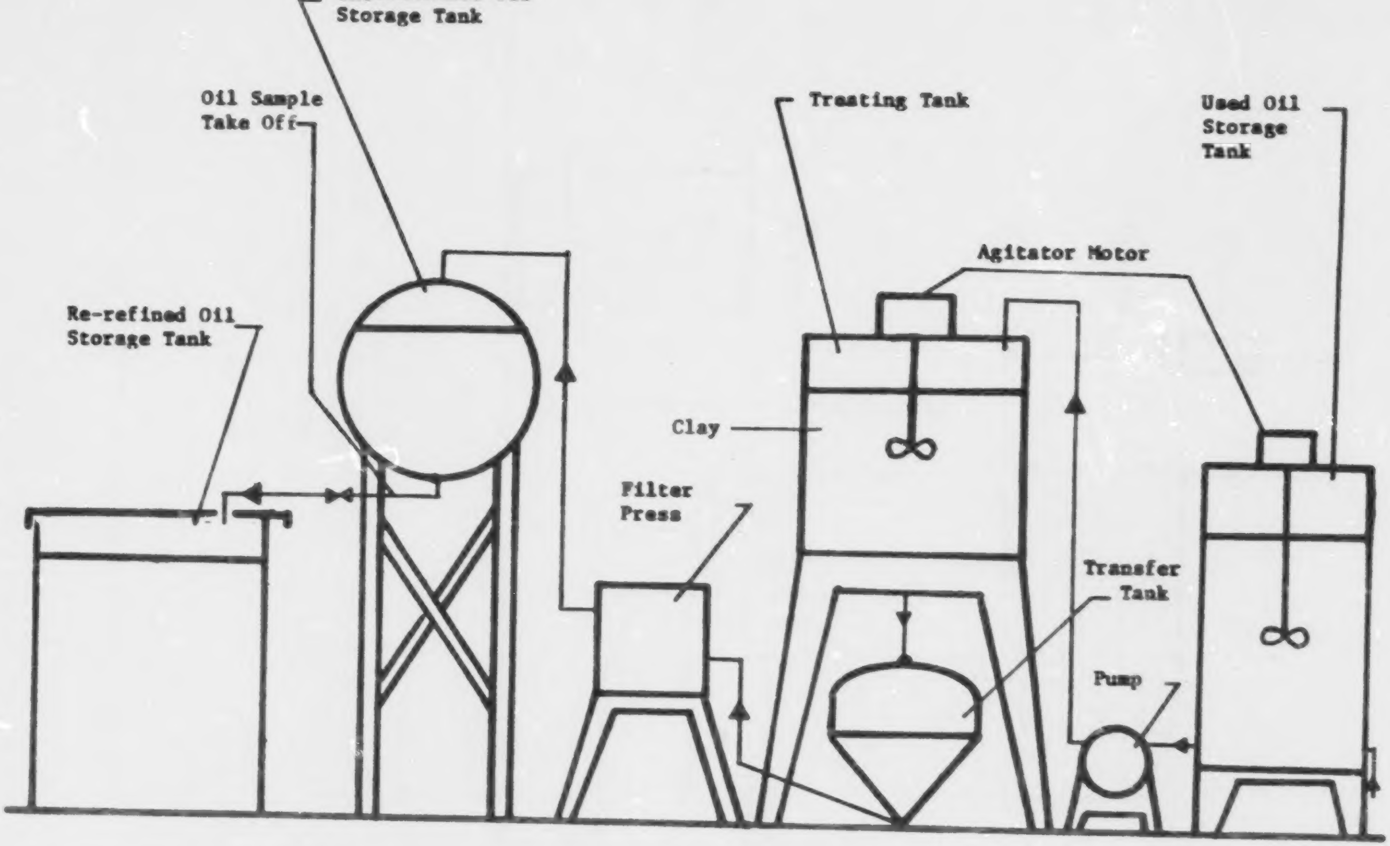

Intermediate Oil Storage Tank
Oil Sample Take Off
Re-refined Oil Storage Tank
Treating Tank
Used Oil Storage Tank
Agitator Motor
Clay
Filter Press
Transfer Tank
Pump

FIGURE 31 . BATCH TYPE CLAY TREATMENT FOR USED OILS (Circa 1949)
(Ref. 36)

The acid and clay treatment process supplanted an earlier process in which waste crankcase oil was first processed by caustic washing or caustic-sodium silicate treating as a pretreatment step; this was followed by a treatment with clay at an elevated temperature and subsequently by steam-stripping and distillation (66). However, the increasing levels of pour point depressants, viscosity index improvers, inhibitors, detergents and dispersants and other materials added to oils, made it necessary for the re-refiners to switch to sulfuric acid treatment to produce a usable product. Thus, the major treatment process during the 1960's involved re-refining with sulfuric acid and clay. These clays consisted of processed natural materials such as Fuller's earth, bentonites and attapulgite. Some of these clays were processed by acid activation and other methods to enhance their adsorptive properties.

Acid treatment involves contacting the oil with 93 to 95 percent or as high as 98 percent sulfuric acid. Sulfuric acid acts as an extraction media for the removal of asphaltenes, unsaturates, dirt, additives, color bodies and other materials from the waste oil. After use, the spent acid consists of organic sulfuric acids of various types, sulfonates and unreacted mineral acid plus oil, all of which must be disposed of as a process waste.

Another adsorption method to purify the lubricating oil requires activated carbon. An example of this is the purification of used diesel engine lubricating oils from railroad service; the purpose of the treatment is to remove various color bodies. In this particular test, various combinations of clay and carbon ranging from zero clay to 100 percent clay indicated that activated carbons were inferior to the clays (67).

Although the activated carbons were inferior to the clays in removing impurities in this particular test, there does not appear to be a great deal of recorded test work in this area. The carbons do have the advantage of being combustible, thus permitting incineration as a possible alternative to getting rid of process wastes. Additionally, activated carbons can be regenerated in large operations, and a licensed process is available for installation (68).

Many of the current practices for the purification of waste crankcase oils have not been patented but are rather specialized approaches used by individual plants. In these processes the operators have attempted to deal with the rising additive content of modern motor oils. In doing so, they have turned to methods which counteract the effect of the acrylic ester polymers present as additives in lubricating oils. Figure 34 illustrates one of the processes (80) used in 1969 for producing an acceptable fuel oil. The essential features of this process are hydrolysis to offset the effect of dispersants and the use of de-emulsifiers to cause separation of the aqueous phase from the oil phase. Subsequently, the separated settled oil is subjected to clay contacting and distillation in a manner similar to that discussed in previous processes. A similar approach using demulsifiers and adsorbents to remove the interfering additive materials followed by centrifugation, acid treatment, additional adsorbent treatment and centrifuging has been reported to be economical as a method of handling relatively small volumes of oil (80).

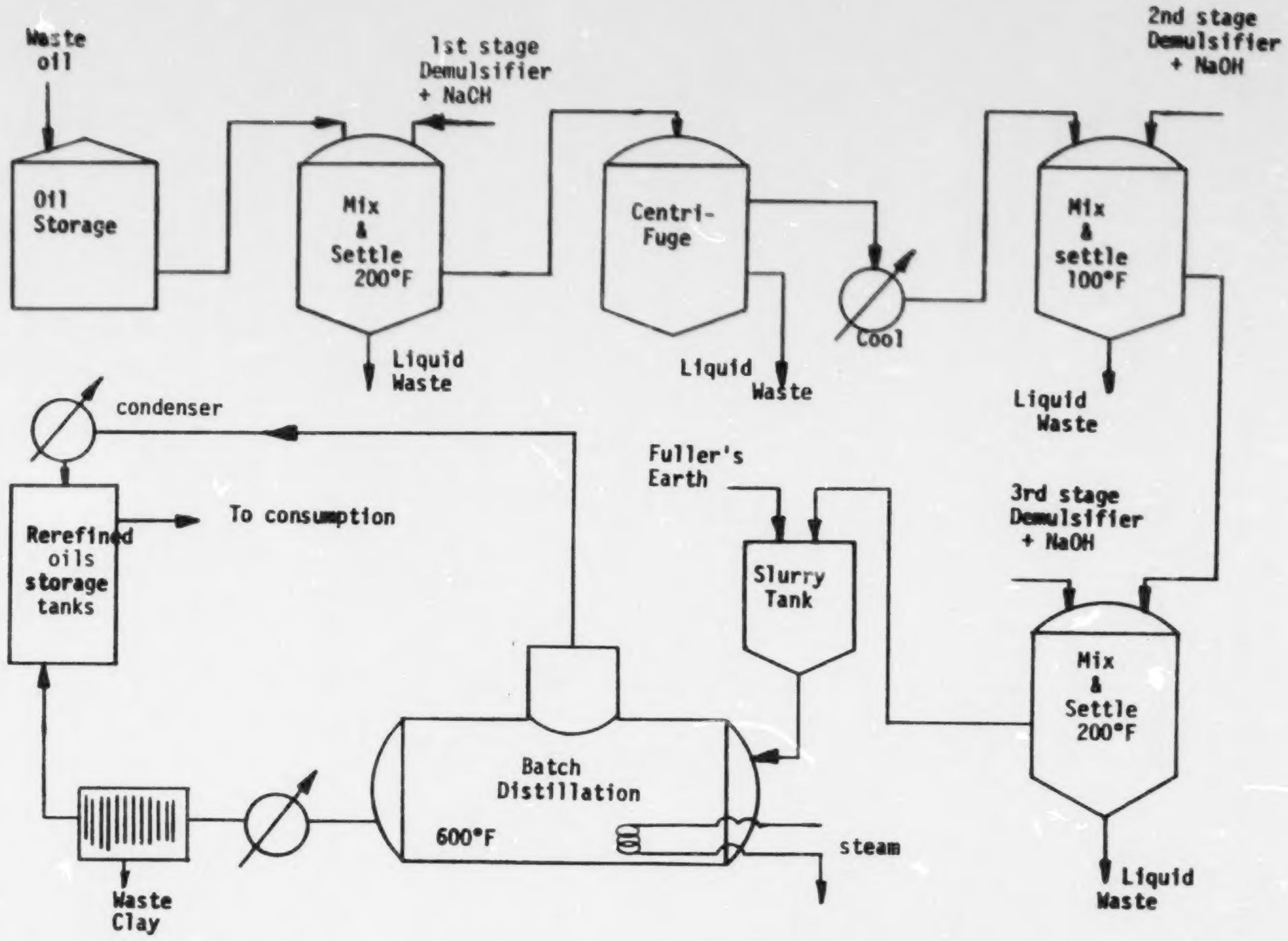

Waste oil
Oil Storage
1st stage Demulsifier + NaCH
Mix & Settle 200°F
Liquid Waste
Centri-Fuge
Liquid Waste
Cool
2nd stage Demulsifier + NaOH
Mix & settle 100°F
Liquid Waste
condenser
Rerefined oils storage tanks
To consumption
Fuller's Earth
Slurry Tank
3rd stage Demulsifier + NaOH
Mix & Settle 200°F
Liquid Waste
Batch Distillation
600°F
steam
Waste Clay

Fig. 34 Waste Oil Re-refining Process (circa 1969)

A process recently reported (81, 82) by Oil Week converts waste crankcase oil into a low sulfur No. 5 fuel oil. Essentially this process comprises the following steps: distillation to remove volatile gasoline and water, filtration to remove sludge and water, and sedimentation to permit lead compounds to settle out. The use of any flocculating or demulsifying aids was not reported nor was the final lead content after settling; however, the sulfur content was reported as being 0.58 percent.

Various combinations of physical and chemical processes with the clay-acid treatment method have been used industrially. In previous sections, the product from such a process was reported in Table 18. The basic steps in this process are distillation to remove water and gasoline followed by mixing with liquid propane. The desirable oil fraction is soluble in the propane and is removed as a continuous stream at the upper portion of an extraction column. Insoluble residues are taken off at the bottom of the column. Subsequent to this propane clarification step, the remaining oil is distilled to recover all of the propane and then treated as described previously by means of acid and clay adsorption.

In work described by Bonnifay (37), the bottoms from the propane extraction step are processed to remove propane which is recycled within the overall treatment process. The basic claims for this particular process combination is a reduction in the amount of acid and clay required to purify the waste oil. A significant aspect of the propane process is the stability of the regenerated oil. When compared with the conventional acid and clay treatment using 9 percent sulfuric acid and 7 percent clay, the resulting oil had an ASTM color of 4 units which increased by 50 percent in 16 hours when held at 185°F. In a comparative test, the propane process produced an oil with an ASTM color of 2 units which rose to 2.9 units within 16 hours without further indication of change. The propane process employed only 2 percent sulfuric acid and 2 percent clay. An industrial plant with an annual capacity of 9 million U.S. gallons has been reported operating successfully since December 1968 in Milan, Italy by the Italian firm Viscolube Italiano. The plant is reported to use 200 kilowatts of electrical power, 1,240 gpm cooling water, 330 lbs. of steam per hour, and 12 million Btu per hour of fuel. The propane loss is estimated at 33 lbs. per hour. The overall yield reported for the process is 92.5 percent exclusive of water and gasoline dilution usually present in the waste crankcase oil. The percent operating time or stream factor for this plant has not been reported.

# SECTION XII

## REVIEW OF EXPERIMENTAL WORK AND METHODS FROM THE PATENT LITERATURE

A large number of patents have been filed on the subject of oil purification and re-refining. Additionally, a great deal of experimental work has been carried out in this area of technology. In the following sections some of the more significant patents and experiments have been reviewed. Since these are all predominantly experimental, it must be concluded that additional work would have to be done to bring these ideas into commercial reality.

The patent literature offers a number of methods for treatment of waste oils. Milliken describes one in which a used crankcase oil is first treated with Fuller's earth to remove asphaltic materials and then is agitated with a 50-50 mixture of aqueous methanol to which has been added a few percent of guanidine carbonate.(69) After settling and washing the oil to remove the methanol, it is claimed that the treated oil is free of acid and has improved oxidation and color stability; further it is claimed that after addition of oxidation inhibitors and dispersants that the treated oil is equal to or better than unused oil containing the same additives.

Smith shows a process(70) for purifying diesel engine lubricating oils by means of treating them with aqueous solutions of salts such as barium, calcium and strontium salts of acetic acid, propionic acid and butyric acid. The process is claimed to reduce the acid number and the corrosion characteristics of the oil without affecting the stability created by the additives originally compounded with the new oil.

A chemical process presented in another patent purifies used crankcase oil after previous treatment with Fuller's earth by treating with aqueous sodium hydroxide and a mixture of a few percent of ethylene sulfate, heated and agitated at about 170°F. Subsequently, the oil is washed until neutral and returned to use. The inventor claims that the treated oil is equal to or even better than the unused oil containing the same oxidation inhibitor and dispersants. In a similar example, the use of 4-hydroxybutanesulfonic acid solution is suggested - similar results are claimed (50).

An invention by Sarui presents a method(71) of regenerating oxidized lubricating oils by contacting them on a series of connected metallic electrode surfaces consisting of alternate pieces of aluminum and magnesium in electrical contact with each other or materials such as silver solder partially coated with tin. These metals are in a configuration of wire baskets or other extended surfaces through which the oil can be passed to cause reaction of the metallic components with the acidic

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products in the oil, thereby forming metallic salts.

Greffin describes a process (72) for treating used oils with nascent hydrogen formed by contacting the oil as an emulsion with a strongly basic solution and an amphoteric metal (Zn, Al). The process claims elimination of all the insoluble impurities including cracking products, oxidation products and color bodies.

A process patented by Glineur presents a method for treating used motor oils by the use of potassium and sodium salts of stearic acid in the presence of carbon.(73) It is claimed that a valuable fatty acid byproduct and reusable regenerated oil is produced.

A hydrogenation process(74) is described for the purification of pretreated used motor oil. The pretreatment consists of conventional acid extraction and separation. Subsequently, the acid-treated oil is hydrogenated in a 75 percent hydrogen/nitrogen mixture using a nickel molybdenum/catalyst on gamma alumina. The hydrogenation is carried out at about 400°F and produces a regenerated motor oil in a yield of 48 percent. Several variations in prepurification prior to hydrogenation are described.

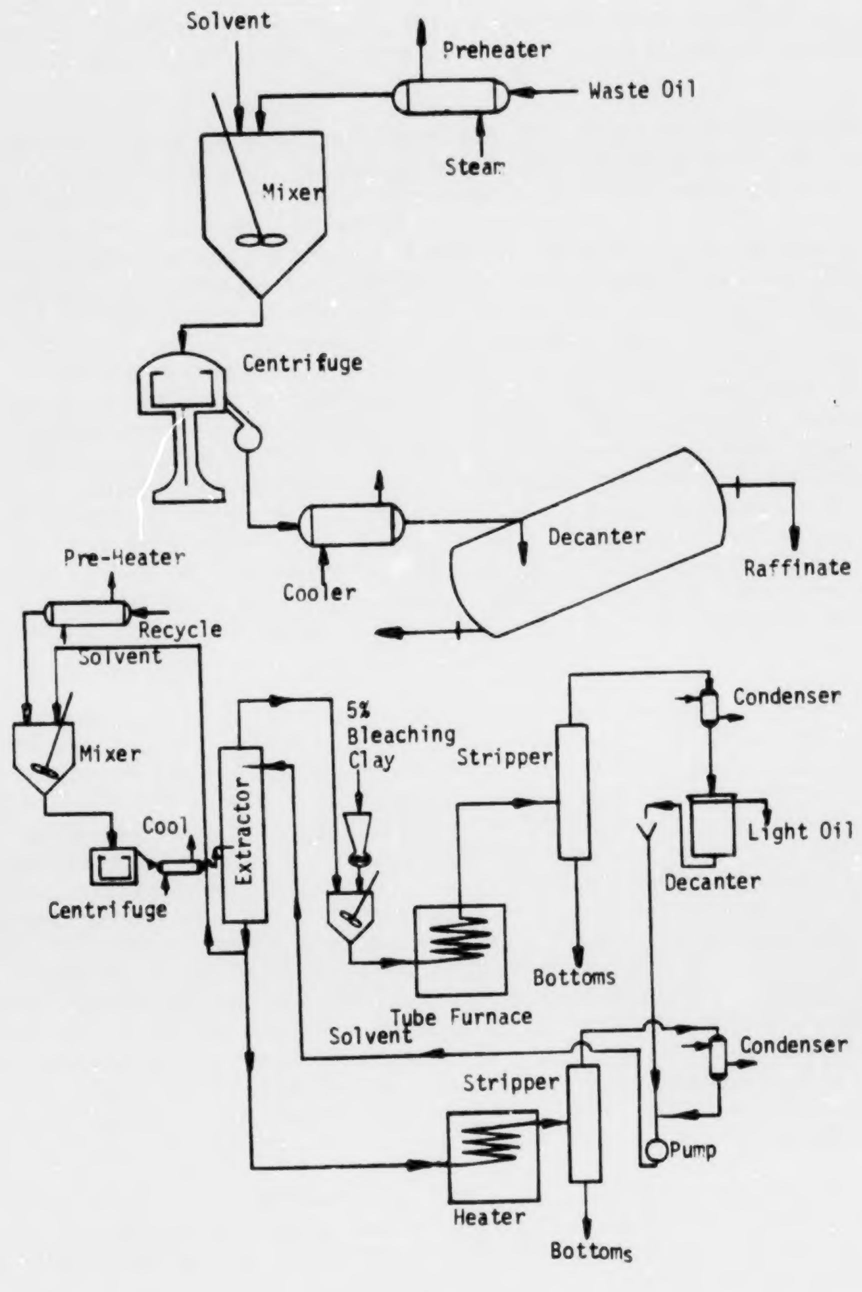
Bernellin's process for removing suspended carbon particles and other suspended carbonaceous materials uses an electrolytic technique.(75) In this procedure, claimed to be superior for detergent type oils which contain additives enhancing suspension of carbonaceous impurities, the oil is electrolyzed in a circular cell using an electrical field of 1,000 to 10,000 volts per cm and a power consumption of one half to five watt-hours per liter of oil. Both diesel oils and gasoline engine oils may be treated by this method; examples cited indicate a 10 to 27-fold reduction in suspended carbon and a small decrease in ash content. A loss in the index of viscosity is noted for both types of oils.

Greffin combines electrolysis and hydrogenation to contact used oil with 0.1 normal caustic soda in the presence of an amphoteric metal such as zinc or aluminum.(76) The process is claimed to result in elimination of all the nonsoluble impurities and much of the soluble impurities without suffering any further cracking, oxidation or other alterations of the oil composition.

In a French patent(77), used motor oils are purified by washing first with dilute sodium hydroxide followed by treatment with .05 to 2-1/2 percent of glycol to cause precipitation of impurities; subsequently, the mixture is separated and the oil returned to use.

Figure 32 depicts a West German process(78) combining solvent extraction with phenol or dichlorodiethylether to cause settling and flocculation of impurities, following by centrifuging, bleaching and distillation to produce a purified motor oil and a light oil product. The oil resulting

Figure 32. Re-Refining Processes for Waste Oils Using a Selective Solvent


Solvent
Preheater
Waste Oil
Steam
Mixer
Centrifuge
Decanter
Raffinate
Cooler
Pre-Heater
Recycle
Solvent
Mixer
Cool
Centrifuge
Extractor
5% Bleaching Clay
Stripper
Condenser
Light Oil
Decanter
Bottoms
Tube Furnace
Solvent
Condenser
Stripper
Pump
Heater
Bottoms

from this purification process was stated to have a density of 0.88, viscosity at 122°F of 7.22 degrees Engler, a viscosity index of 102, a neutralization number of less than 0.03 and an ash content less than 0.003 percent.

Kettlitz describes a process (79) for regenerating used motor oils using a molybdenum-cobalt or tungsten and tungsten-nickel type catalyst in a hydrogen refining-type process. Figure 33 shows the basic elements of this process in which a prepurified used motor oil treated, for example, by phenol refining or other method to remove and settle out the detergents, antioxidants and other additives, is charged into a catalytic reactor along with hydrogen at a pressure of 50 to 150 atmospheres and a temperature of 330 to 360°C. The hydrogen-refined stock is then separated from the impurities consisting primarily of hydrogen sulfide, ammonia and water originating from the hydrogenation of sulfur-bearing compounds, nitro compounds and oxygen-bearing contaminants, respectively. Subsequently, these are separated by steam distillation in a stripping tower which removes the volatile materials including low-boiling hydrocarbons. A light product with good viscosity characteristics is claimed as a yield from the process. For example, products such as white oil, transformer oil or turbine oil can be produced. The volume ratio of hydrogen to oil is stated as ranging from 500 to 45,000; these values should be considered as extreme limits. The reported space velocity for this operation is 0.2 reciprocal hours.

A recent patent by Fiedler (83) uses propane extraction and a hydrogenation process for re-refining used lubricating oils. In the process described, waste crankcase oil was first distilled to remove water and fractions boiling less than 350°F. Subsequently, the oil is extracted with propane using a propane-oil ratio ranging from 4-10:1 and then hydrogenating the propane extract (now separated from the propane) over a nickel-molybdenum catalyst on alumina, using a pressure of 100 to 300 atmospheres at a temperature of 320 to 350°F with a space velocity of 1.0 reciprocal hours. Prior to purification the waste crankcase oil had a density of 0.75 grams per cubic cm, a neutralization number of 0.54, a flash point of 100°F, a settling point of -30°F and 0.77 percent solids. After treatment, using a hydrogen-to-oil ratio of 500 to 1, a product resulted having a density of 0.884 grams per cubic cm, a viscosity of 69.5 centistokes, a neutralization number of 0.03, a flash point of 228°F, a settling point of -14°F and a sulfur content of 0.18 percent. This process bears some similarity to the one described in Figure 33.

One of the important effects of sulfuric acid treatment is removal of sludge present as a finely divided precipitate in the waste crankcase oil. A good deal of work has been performed to find substitutes for sulfuric acid because of the difficulty of disposing of acid sludge.

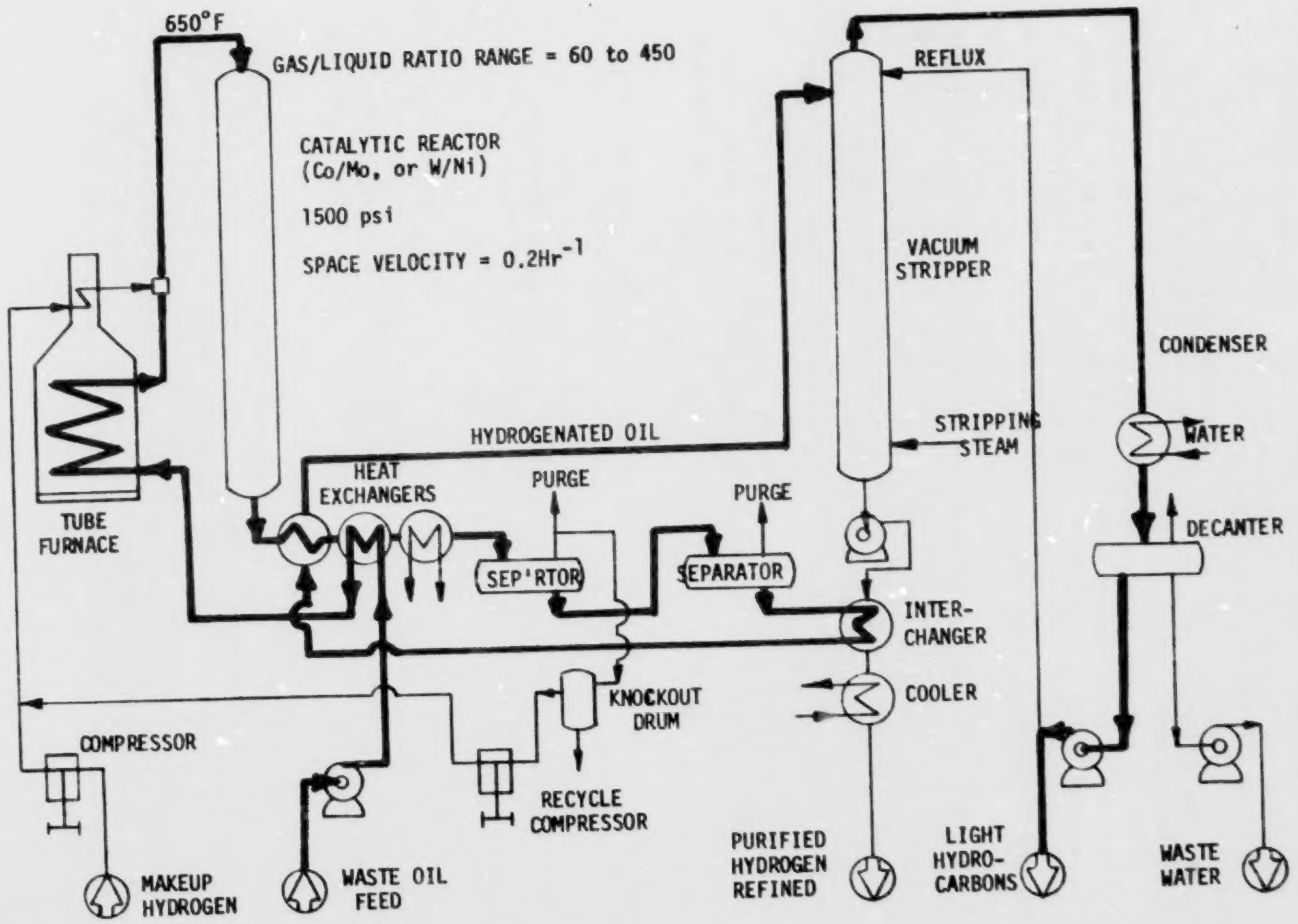

650°F
GAS/LIQUID RATIO RANGE = 60 to 450
CATALYTIC REACTOR (Co/Mo, or W/Ni)
1500 psi
SPACE VELOCITY = 0.2Hr$^{-1}$
TUBE FURNACE
HEAT EXCHANGERS
HYDROGENATED OIL
PURGE
SEP'RTOR
PURGE
SEPARATOR
REFLUX
VACUUM STRIPPER
STRIPPING STEAM
CONDENSER
WATER
DECANTER
INTER-CHANGER
COOLER
KNOCKOUT DRUM
COMPRESSOR
RECYCLE COMPRESSOR
MAKEUP HYDROGEN
WASTE OIL FEED
PURIFIED HYDROGEN REFINED
LIGHT HYDRO-CARBONS
WASTE WATER

FIG. 33 HYDROGEN OIL REFINING PROCESS (W. GERMAN PATENT # 1,182,377)

In work by Putscher, 19 chemical agents were evaluated for use as sludge flocculants; of these, six were found to have some effect(84). Table 27 lists the materials found effective in this study. A large number of chemicals evaluated as sludge flocculants were very poor. It is interesting to note that of the ineffective materials evaluated as sludge flocculants, the following materials did give weak positive results. These are: ferrous chloride, diphenylguanidine, sulfonated castor oil and N-phenylethanolamine. Because of the higher weight percents required for stannic chloride and phosphoric acid (as shown in Table 27) coupled with their high unit costs, these materials are not economically attractive. In this same study the precipitation of sludge by the use of solvents was evaluated.(84) Table 28 lists the solvents giving effective results and the temperatures of treatment.

Putscher's work also included evaluation of sludge flocculation treatment methods comparing six methods of treatment including 40 percent trichloroethylene solvent precipitation, 0.5 percent triethanolamine chemical flocculation and 1 percent, 2 percent and 5 percent sulfuric acid treatment followed by clay filtration and distillation. Table 29 recaps the results of this work. Inspection of these results shows that the color stability of the solvent and chemical flocculation methods is much poorer than that for sulfuric acid. Similarly, the color level itself is higher than that found in sulfuric acid treatment. These researchers used aluminum chloride up to one percent and did get improved performance; however, the high cost of this reagent militates against its use.

In a parallel effort(85) the solubility of the waste crankcase oil in a variety of solvents was studied with a view toward using them for purification by extraction. A series of six solvents, including some that are used commercially for lubricating oil base stock manufacture were evaluated over temperatures ranging from 91 to 288°F. The results of this work by Putscher and colleagues is shown in Table 30.

The analysis of the raffinate after removal of the solvents shows that the ash content of the purified oil layer was as high as 0.27 percent for the phenol solvent extraction; the presence of this ash indicates that solvent extraction alone does not necessarily lead to a purified oil.

Aqueous surfactants also were tested by Putscher as a means of precipitating the oil-soluble detergent component of waste crankcase oils.(85) Some of the materials used include: Triton X-200 (Rohm & Haas), Aerosol AY (American Cyanamid Co.), Separan NP 20 (Dow Chemical Co.), Polyox WSR-35 (Union Carbide) and Nalco 600 (Nalco Co.). These materials were used at a ratio of one part of solution to one part of waste oil; all of these were found to be ineffective and did not result in any purification of the oil.

## TABLE 27

## SLUDGE FLOCCULATION CHEMICALS

(Ref. 84)

| Chemical | Wt. % | Temperature °C | Flocculation Results |
|---|---|---|---|
| Anhydrous Aluminum Chloride | 0.5 | 120 | very good |
| Stannic Chloride | 4.0 | 75 | good |
| Diethanolamine | 1.0 | 75 | very good |
| Triethanolamine | 1.0 | 85 | very good |
| Phosphoric Acid | 2.0 | 90 | good |
| Sulfuric Acid (for comparison only) | 0.5 | 75 | very good |

# TABLE 28

## EFFECTIVE SLUDGE FLOCCULATION SOLVENTS

(Ref. 84)

| Solvent | Temperature °C |
|---|---|
| Trichloroethylene | 30 |
| Monochlorobenzene | 50 |
| Nitrobenzene | 30 |
| Dioxane | 50 |
| Pyridine | 50 |
| Benzaldehyde | 75 |
| Chloroform | 30 |

## TABLE 29
## CHEMICAL TREATMENT OF WASTE CRANKCASE OIL
(Ref. 84)

|  | I<br>Trichloroethylene<br>40% | II<br>Triethanolamine<br>0.5% | III<br>Anhydrous Aluminum Chloride 0.5% | Conc. Sulfuric Acid<br>IV<br>1% | <br>V<br>2% | <br>VI<br>5% |
|---|---|---|---|---|---|---|
| Sludge Collected, Wt.% | 5 | 4.7 | 8.9 | 5.5 | 4.0 | 5.6 |
| Filtrol Clay added, lb/gal | 0.7 | 0.37 | 0.37 | 0.37 | 0.37 | 0.44 |
| Distillate, Wt.% | 9 | 6 | 4 | 3 | 6 | 16 |
| Finished Oil, Wt.% | 67 | 77 | 76 | 81 | 77 | 64 |
| Color NPA After Treatment | 6-1/2 | 8 | 7 | 8+ | 4-1/2 | 3 |
| Color After 3 Weeks | 7-1/2+ | - | 8 | - | 6 | 3 |
| API Gr. | 28.5 | 28.9 | 28.4 | 29.2 | 29.3 | 29.2 |
| $SUS^{100}$ | 303.7 | 355.0 | 340 | 334.2 | 335.0 | 384.4 |
| $SUS^{210}$ | 53.9 | 57.4 | 56.5 | 56.2 | 56.1 | 58.6 |
| VI | 107 | 108.5 | 109.0 | 109.5 | 108.5 | 105.0 |
| Acid No. | 0.54 | 0.64 | 1.2 | 0.18 | 0.16 | 0.45 |
| Flash Point | 410 | - | - | 420 | - | 450 |
| Fire Point | 455 | - | - | 470 | - | 495 |
| Ash, Wt.% | 0.46 | 0.58 | - | - | - | - |

## TABLE 30

## CRANKCASE OIL - SOLVENT MISCIBILITY

| Solvent | Solvent/Oil Ratio | Miscibility Temperature °F | Observations |
|---|---|---|---|
| Phenol | 1:1 | 205 - 209 | Separation at 190°F, clean oil layer |
| O-Cresol | 1:1 | approx. 130 | Separation at 120°F, clean oil layer |
| 60% Phenol/ 40% Cresol | 1:1 | approx. 140 | Poor phase separation |
| Furfural | 1:1 | 288 | Separates at 280 °F, clean oil layer |
| Chloroaniline | 1:1 | 91 | Separates at 88 °F, clean oil layer |
| Nitrobenzene | 1:1 | 115 | Poor phase separation |

Some mention has been made in the literature to other types of processes which may be useful in the future for the purposes of purifying waste automotive and industrial oils. In the following paragraphs, a number of these experimental processes will be discussed to indicate the level and scope of activity in this field.

Nyal suggests the use of chromatography to refine lubricant stocks.(86) These researchers used both one- and two-stage elution methods for refining the feedstocks. A comparison made with the acid refining process resulted in lower requirements for chemicals and raw materials to produce a unit of finished oil. However, a greater amount of heat was required to recover solvent and a large amount of adsorbent was required for the chromatographic columns. The pilot work was carried out in a continuous column to refine spindle and lube oil; the columns were reactivated by either heating the solvent for extraction or substituting a more polar solvent for this step.

Earlier, Groszek applied chromatography(87) to a lubricating oil containing polymethacrylates (which are frequently used as additives in automotive engine oils) by treating it in a silica gel column for partial separation of the high molecular weight polymethacrylates from the lubricating oil fraction. The method was found to be useful for separating polymers having a molecular weight greater than 10,000. In the operation described, the oil containing the polymethacrylate was dissolved in n-heptane and then passed through a column. This type of technology could prove useful not only in separating the additives from the lubricating oil fraction but also in enabling recovery of the additive material.

Livingston describes a process in his patent(88) for re-refining lubricating oil to purify both used crankcase and industrial oils. An adsorbent catalyst such as MgO,$SiO_2$, bentonite, activated alumina or activated clays and activated carbon having a particle size of approximately 100 mesh is mixed with the oil and heated to 350 to 650 °F while air is blown through the oil for a period of time ranging from 10 to 30 minutes. Subsequently, steam is passed through the oil to displace the air after which the mixture is cooled and the oil recovered by means of filtration. As an additional step, the oil may be subjected to the usual sulfuric acid treatment described previously; the resulting oil product is reported to have qualities equal to those resulting from clay/acid treatment processes. The use of air for mixing and oxidizing impurities in the waste oils have also been reported for a commercial re-refiners operation (89).

Hill and Munsal report that dialysis is useful in separation of detergents from waste crankcase oils(90). In this experimental work, thin-walled rubber membranes were dialyzed using a circulating solvent on one side of the rubber membrane and the waste crankcase oil on the other side of the membrane. The dialysate recovered was approximately 86 percent and the residue remaining, 14 percent. The residue contained much of the colloidal detergent material; unfortunately the recovered dialysate contained 0.2 percent ash indicating that additional separation processes would be necessary to remove dissolved metallorganic materials.

Dietrick has patented methods for removing metal compounds in a petroleum refining process patent(91). In this process, aqueous solutions of compounds including n-Guanylthiourea carbonate, thiosemicarbazide, beta-hydroxyethylmercaptan, cystein hydrochloride, 1, 10 decanedithio and lauryl mercaptans ranging in concentration from 0.1 to 10 percent with one percent solutions being preferred, are used to extract heavy metals including copper, iron, cobalt, manganese and vanadium from benzene, fuel oil or gasoline containing these metals. In one example cited, 500 ppm of copper was removed from a benzene solution by using a one percent solution of thiosorbitol in a volume equal to the benzene solution. Complete extraction of the copper was reported. This type of process could find use as a method for removing any interferring metals found in lubricating oil recovered from re-refining operations.

Other aspects of petroleum technology used for processing crudes and gas oils into lighter distillates have some significance for the re-refining of waste lubricating oil. One of the processes is hydrocracking(92). In this process the feed hydrocarbon is brought into contact with hydrogen at a high pressure and temperature over a catalyst. The ability of this process to function with waste oil feeds bearing metallic compounds remains to be demonstrated. When oil stocks are subjected to this type of treatment they undergo cracking, isomerization, disproportionation, hydrogen transfer, and cyclization, if the feedstock is predominantly a paraffin. If the feed is an aromatic, then either partial or complete hydrogenation takes place and the transfer of alkyl side chains and isomerization occur. Naphthenic bodies and other cycloparaffins usually are de-alkylated, isomerized and subjected to ring cleavage in the hydrocracking process. In a single stage hydrocracking operation using a feed characterized as a gas oil and having a gravity of 45.6° API, a product having an initial boiling point of 303°F, an end point of 539°F, a flash point of 112°F and 8 percent aromatics by volume was produced. In the single stage process, the catalyst must be resistant to the poisoning effects of sulfur or nitrogen. In the two stage hydrocracking process, a feed pretreatment to remove all nitrogen and sulfur compounds and saturate the aromatics by hydrogenation is used. Subsequently, the contaminant-free feed is further processed in a second reactor where it is hydrocracked over catalysts which are easily poisoned by sulfur and nitrogen contaminants. The catalysts used for the single stage operation generally consist of metal oxides of nickel or cobalt plus tungsten or molybdenum supported on refractory metal oxides. In the two-stage treatment system, the second stage catalyst uses hydrogenation-type catalysts such as nickel, platinum or palladium supported on refractory oxides. Specific catalysts used include platinum, nickel and tungsten sulfide on amorphous silica-alumina and various metals deposited on molecular sieve supports. Products that result include light distillates such as kerosene, jet fuel, diesel oil, furnace oils and similar materials.

Some preliminary work on the use of hydrogenation for re-refining waste lubricating oil has been carried out(93). In this work, a vacuum-distilled material containing approximately 75 percent of the original waste lube oil charged to the process but minus the low boiling materials such as diluent gasoline and minus the heavy residual bottoms product was charged into a single stage hydrotreating process using a commercially available hydrotreating catalyst; operating pressures were 600 psig at a temperature of approximately 700°F and a hydrogen-to-oil feed ratio of 260 to 1. The space velocity for this operation was 1.0 reciprocal hours. The feed to this process had the following analysis: sulfur - less than 0.07 percent, gravity - 30.5° API, nitrogen - 256 ppm, lead - 2 ppm, calcium - 0.25 ppm, iron - 0.37 ppm, ASTM color - 7.5. The initial boiling point of the material charged was 408°F and the end point was 925°F (99 volume percent recovered). The product recovered from this hydrogenation operation had the following characteristics: sulfur - less than 0.07 percent, gravity - 32° API, nitrogen - 79 ppm, lead - 0.05 ppm, calcium - 0.05 ppm, iron - 0.97 ppm, ASTM color - 3.5. The initial boiling point of this hydrogenated product was 418°F and the final boiling point was 885°F. Another important observation was the absence of any odor in the product. However, solid particulate material which settled out on standing was observed in the hydrogenated product. The forty-fold decrease in lead concentration indicates that this process may be attractive for the preparation of recovered oils requiring the absence of metallic constituents.

Another process which may have application for the re-refining of waste oil feeds into more useful materials include cracking processes for the manufacture of olefins. Olefins are important reactive materials used in large quantities to produce detergents, for example, and a whole variety of petrochemical and organic products. A process for steam cracking wax feedstocks is described in Figure 35. This process will produce C-6 to C-20 olefins from wax feedstocks in an 80 percent yield(94). The product split has been reported to be about 25 percent C-4 olefins and 75 percent C-5 to C-19 olefins. More than 90 percent of the olefins produced are mono-olefins; di-olefins constitute the major impurity. The light-weight olefins are suggested as a use for an Oxo process feed, while the higher molecular weights are suitable for detergent production. This process is a thermal one and does not require the use of catalytic reactors.

A catalytic cracking process (43) using a heavy oil feedstock having an initial boiling point around 350°F and an end point around 690°F produces low molecular weight olefins such as ethylene and propylene in yields of 35 percent. Both of these products have ready application in the production of polymers. The suitability of these catalytic-type heavy oil cracking processes for handling waste crankcase oils contaminated with heavy metals has not been determined; however, purification to remove the heavy metals would be necessary to utilize the previously described catalytic process.

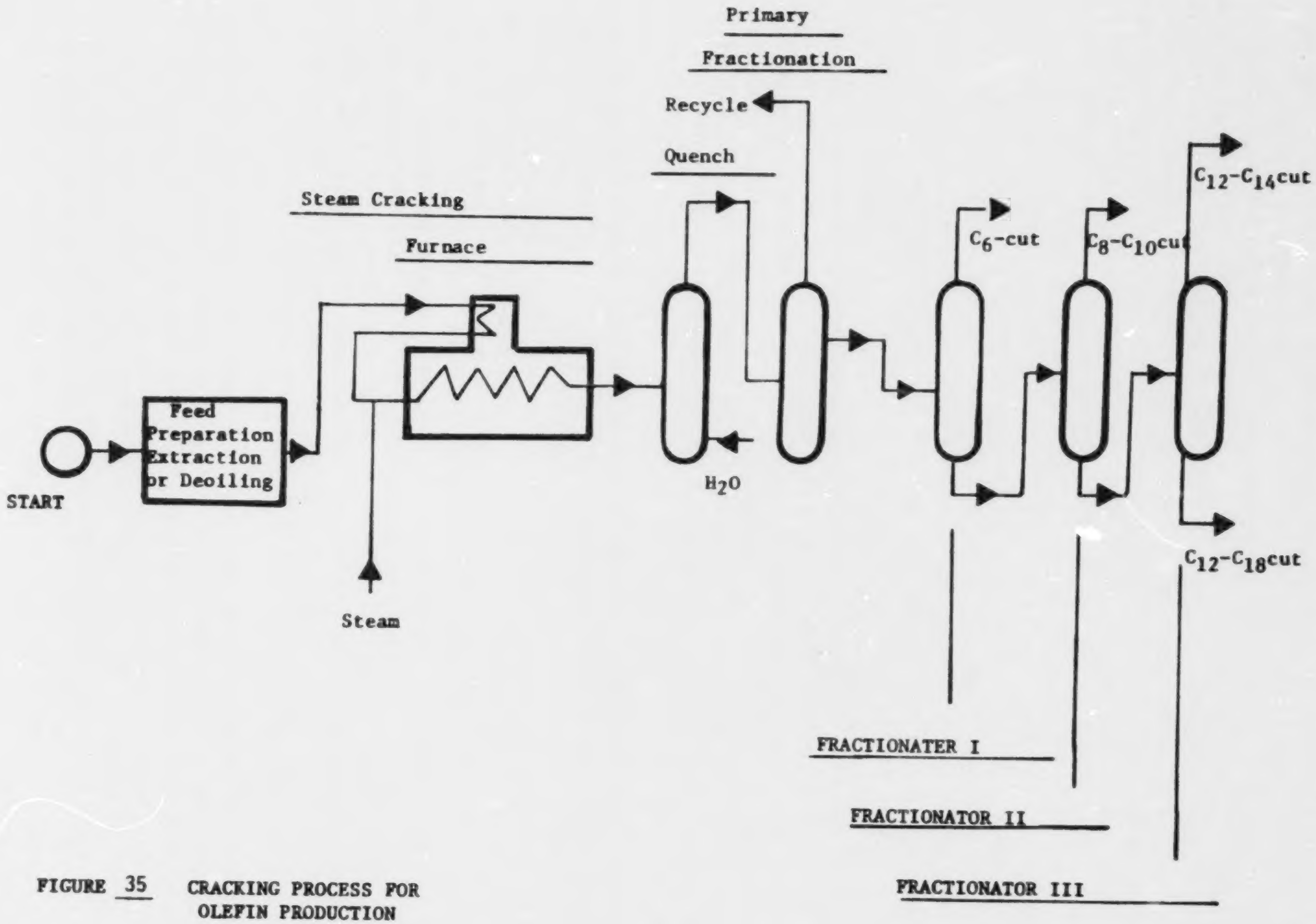

START
Feed Preparation Extraction or Deoiling
Steam Cracking
Furnace
Steam
Quench
$H_2O$
Recycle
Primary
Fractionation
$C_6$-cut
$C_8$-$C_{10}$cut
$C_{12}$-$C_{14}$cut
$C_{12}$-$C_{18}$cut
FRACTIONATER I
FRACTIONATOR II
FRACTIONATOR III

FIGURE 35 CRACKING PROCESS FOR OLEFIN PRODUCTION

The use of waste oils as an alternate feed to the steam cracking process is potentially applicable since heavy metals do not affect this process as much as catalytic ones. A pilot plant using this process has been operated(44) on a gas/oil feedstock typically having an initial boiling point of 400°F and a final boiling point of 650°F; additionally, sulfur ranged from 0.1 to 0.2 percent. The composition of the feedstock was 35 to 40 percent paraffins, 35 to 40 percent naphthenes and 25 to 30 percent aromatics. This purely thermal process, depending on the severity of the operation, yields 40 to 48 percent C-3 and lighter hydrocarbons of which one fifth was methane and hydrogen. The balance of the product includes about 10 percent mixture of butane and butene, about 6 percent C-5 compounds and a residual liquid material in a yield of about 20 percent and boiling over the range of 400 to 650°F. A bottoms product of about 5 percent boiling at 650°F and over resulted from this process. Steam dilution in the range of 0.6 to 0.8 lbs. per lb. of feed is used in the process.(44)

Because of the purely thermal nature of this process, that is, the absence of any catalytic beds or reactors, the applicability of this process to treating waste oil stocks may be attractive; no work has been reported on the treatment of waste oil stocks by this method.

The conversion of olefins discussed in previous cracking processes into detergent stocks is important since olefins may be converted to valuable alkanesulfonates. In a process reported by Norton (95) the reaction is carried out in the presence of an aqueous solution of isopropanol, potassium nitrate and sodium bisulfite, the mixture being contacted with air to supply the oxygen to form the sulfonate. After neutralization with caustic soda and extraction with hexane, the raffinate is distilled to recover oils and solvent while the bottoms product is distilled to recover solvent and alkanesulfonate. Figure 36 illustrates this process for utilizing olefin reactants to produce valuable products. Another process which can make use of olefins is the Oxo process(96) which can yield aldehydes, alcohols and ketones.

Silver and Cooper describe a process (97) for the conversion of n-Paraffins into edible proteins for animal feed (see Fig.37 ). Currently, this process is being considered for full scale commercialization to produce single cell protein. In the process described, the normal paraffin content was 96 weight percent and the number of carbons ranged from C-11 to C-17. The single cell protein used in this process is a special yeast and has been reported to grow both in pure paraffins or even crude distillates. An important caution presented by the authors is that carcinogenic polynuclear aromatic material must be removed to prevent its occurrence in the single cell protein since the presence of such carcinogens would make it unfit for human or animal feed. Application of this process at this time for the conversion of waste oils is conjectural.

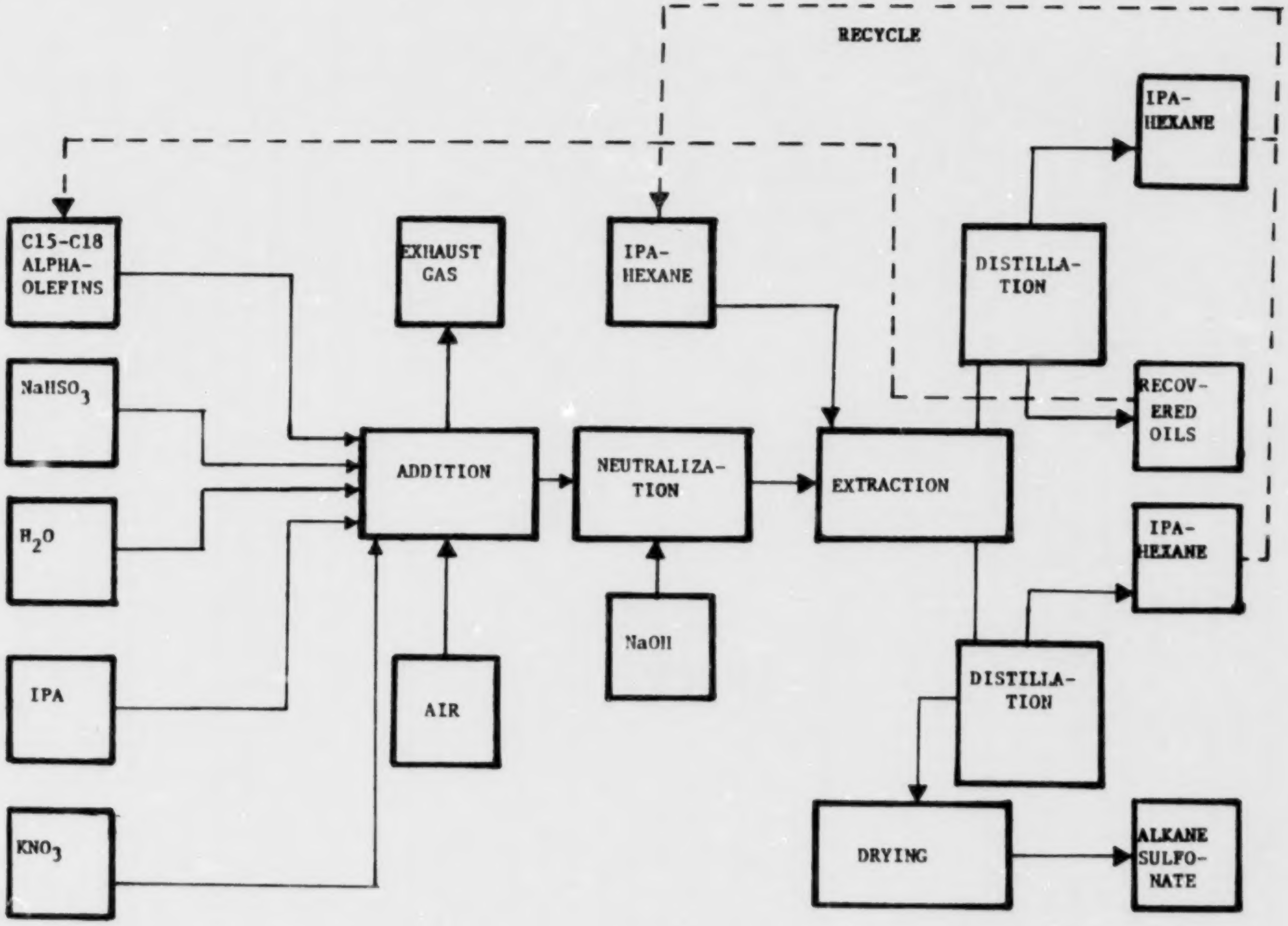

RECYCLE
C15-C18 ALPHA-OLEFINS
$NaHSO_3$
$H_2O$
IPA
$KNO_3$
EXHAUST GAS
ADDITION
AIR
IPA-HEXANE
NEUTRALIZA-TION
NaOH
EXTRACTION
DISTILLA-TION
IPA-HEXANE
RECOV-ERED OILS
IPA-HEXANE
DISTILLA-TION
DRYING
ALKANE SULFO-NATE

FIGURE 36. PROCESS FOR DETERGENT MANUFACTURE FROM OLEFINS

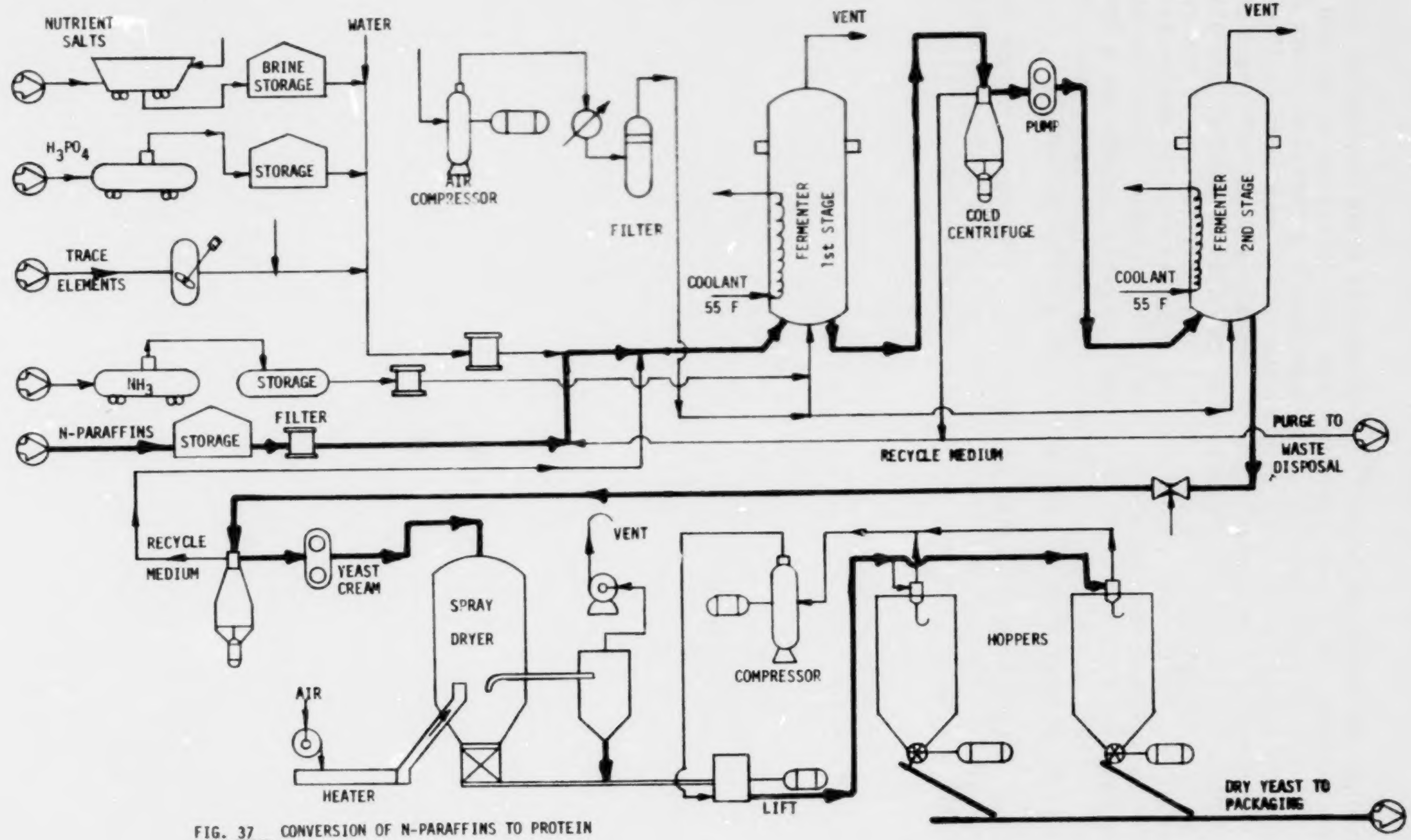

NUTRIENT SALTS
BRINE STORAGE
WATER
$H_3PO_4$
STORAGE
AIR COMPRESSOR
FILTER
TRACE ELEMENTS
$NH_3$
STORAGE
N-PARAFFINS
STORAGE
FILTER
VENT
COOLANT
55 F
FERMENTER 1st STAGE
COLD CENTRIFUGE
PUMP
VENT
COOLANT
55 F
FERMENTER 2ND STAGE
PURGE TO WASTE DISPOSAL
RECYCLE MEDIUM
RECYCLE MEDIUM
YEAST CREAM
SPRAY DRYER
VENT
AIR
HEATER
COMPRESSOR
LIFT
HOPPERS
DRY YEAST TO PACKAGING

FIG. 37 CONVERSION OF N-PARAFFINS TO PROTEIN

In a similar operation overseas(98) a commercial protein-from-oil plant has been designed and was to have been put into operation by the end of 1971. The charge stock for this, the Grangemouth process, utilizes purified feedstock consisting of C-10 to C-18 alkanes which have been purified by means of molecular sieves starting with kerosene and gas oil fractions. Another process, the Lavera process, also employed in another operating train at this location, is to use gas oil feedstock boiling in the range of from 660 to 700°F. The Lavera process requires washing the protein products to remove unfermented oil. The Lavera process is carried out in a pH range of 4 to 6 percent to prevent bacterial growth and a temperature of 86°F is maintained. Depending on the feedstocks used, the yield can be greater than 100 percent of the paraffins charged.

Additional interest in this area of technology is evidenced by the recent commissioning of a study of protein production from industrial wastes by the University of Cardiff's Wolfson Laboratory in London(126).

# SECTION XIII

## ALTERNATE DIRECT AND INDIRECT WASTE OIL DISPOSAL TECHNIQUES

In addition to the physical and chemical treatment processes described in previous sections, a variety of techniques for disposing of waste oil have been utilized. Currently, the methods of greatest prominence are incineration, landfill and dumping. Deepwell injection is another method of importance but primarily useful for the disposal of oilfield wastes in production, operation and drilling. In addition to the direct disposal techniques just described, indirect disposal methods including the use of waste crankcase oil for dust control (road oiling), the direct application of waste crankcase oils to livestocks (notably pigs) for the control of skin pests, the admixing of crankcase oils with oil dispersed insecticides and indirect disposal by using the waste oil as a fuel have been used. Of these indirect disposal methods, road oiling and fuel use appear to be the most extensive applications.

Because of the similarity between incineration and the use of waste oil as a fuel, these will be discussed as a unit in the following. The combustion of waste oils must take into consideration the composition of the oil charged to the incinerator or furnace. For example, crankcase oil described in previous sections has large amounts of metallic additives which are not combustible but lead to the formation of metallic oxides which are discharged with the combustion gases. The composition of these combustion products depends on the area from which the oil is procured; however, about 100 lbs. of combustion products generally result from a thousand gallons of waste crankcase oil (33). This is shown more clearly in Table 31. Although the composition of these products of combustion vary from location to location, there is a definite uniformity in their total mass.

In a series of burning tests carried out by the American Petroleum Institute (9), it was concluded that waste crankcase oil could be burned for steam generation under conditions essentially the same as for No. 6 fuel oil; however, several tests indicate the formation and deposition of ash both on burners and on tubes when firing with 100 percent waste oil. Firebox deposits (slag) and soot from tubes had large amounts of lead and other metals as shown in Table 32. Combustion also was accompanied by the presence of deposits within the chimney itself. Testing with different types of burners indicated that mixtures of No. 2 oil with crankcase oil could be burned easily with low or high pressure domestic-type gun burners when the waste oil concentration is approximately 50 percent or less. At higher concentrations, the low pressure (less than 3 psig) gun burners gave superior results.

Small amounts of waste oil can be incinerated in a water cooled incinerator having a preheated basin fed with oil by a gravity feed mechanism. Commercial units burning 10 gph are available and can supply approximately 10 gpm of hot water at a temperature rise of 80°F. Solids are retained in the basin and must be removed periodically (99). This type of incin-

TABLE 31
WEIGHT OF COMBUSTION PRODUCTS FROM WASTE CRANKCASE OILS
POUNDS PER 10,000 GALLONS (CALCULATED AS OXIDES)
(Ref. 33)

| | Jackson Miss. | Okla. City Oklahoma | Washington D.C. | Doraville Georgia | San Carlos Calif. | Dearborn Mich. | St. Louis Missouri | Houston Texas | Lyons Ill. |
|---|---|---|---|---|---|---|---|---|---|
| Zinc | 36 | 46 | 58 | 33 | 54 | 45 | 32 | 32 | 44 |
| Copper | 1.1 | 0.9 | 1.4 | 1.2 | 1.6 | 1.4 | 1.2 | 1.3 | 1.5 |
| Aluminum | 4.6 | 5.1 | 2.6 | 5.1 | 4.4 | 4.8 | 4.5 | 4.4 | 6.3 |
| Barium | 43 | 25 | 57 | 20 | 31 | 9.3 | 33 | 45 | 38 |
| Calcium | 136 | 220 | 162 | 131 | 220 | 147 | 120 | 162 | 168 |
| Nickel | 0.2 | 0.3 | 0.3 | 2.4 | 0.5 | 0.6 | 0.3 | 0.9 | 0.7 |
| Chromium | 2.6 | 2.9 | 4.8 | 1.5 | 3.8 | 2.6 | 2.2 | 2.9 | 1.2 |
| Iron | 34 | 32 | 17 | 30 | 28 | 36 | 32 | 30 | 42 |
| Silicon | 29 | 22 | 13 | 24 | 24 | 27 | 64 | 19 | 24 |
| Lead | 650 | 650 | 400 | 570 | 480 | 720 | 650 | 570 | 650 |
| Tin | 0.6 | 0.6 | 0.6 | 1.0 | 0.9 | 1.0 | 0.9 | 1.3 | 0.9 |
| Phosphorus | 225 | 225 | 255 | 211 | 173 | 264 | 189 | 189 | 173 |
| Boron | 3.6 | 3.6 | 2.8 | 4.3 | 3.6 | 5.9 | 3.6 | 3.8 | 5.9 |
| Magnesium | 23 | 10 | 23 | 36 | 19 | 31 | 25 | 61 | 25 |
| TOTAL | 1188.7 | 1243.4 | 997.5 | 1070.5 | 1043.8 | 1295.6 | 1157.7 | 1122.6 | 1180.5 |

## TABLE 32

## COMPOSITION OF FIREBOX AND TUBE DEPOSITS RESULTING FROM WASTE OIL COMBUSTION

| Item | Firebox Deposit | Soot from Tubes |
|---|---|---|
| Appearance | Purple agglomerates,<br>Rock hard, 1/2" pieces | Dark Grey powder,<br>Heavy soot |
| Bulk Density | -- | 0.9 |
| % Combustible | Nil | 6.0 |
| | | |
| Barium | 12.0 % | 3.6 % |
| Calcium | 8.8 | 2.2 |
| Zinc | 3.3 | 2.6 |
| Phosphorus | 10.4 | 3.3 |
| Iron | 2.8 | trace |
| Lead | 28.0 | 43.0 |

erator will burn oil bearing up to 10 percent water. Forced draft incinerators are preferred since they permit greater heat release per unit of furnace volume. Incinerator temperatures ranging from 1200-1800°F usually are adequate for complete combustion of most waste oils. Frequently, this is best accomplished using an auxiliary burner fired with gas or light oil to maintain furnace temperatures in the case of difficult-to-ignite oil wastes (23). In this case, the waste oil is sprayed into the combustion space where it vaporizes and ignites. Important factors for incinerator operation are maintaining adequate residence time in the combustion zone, keeping the operating temperature adequately high and maintaining adequate turbulence in the combustion zone. Most waste oils are incinerated in vertical or horizontal refractory-lined furnaces. Units having atomizing nozzles can be clogged easily since they have small apertures.

If the waste oil being incinerated contains large amounts of hazardous solid materials (e.g., lead), the flue gases may require treatment for removal of particulates. This may be accomplished by cyclones, electrostatic precipitation and by wet scrubbing. Hazardous gaseous wastes such as hydrogen chloride (HCl) cannot be removed except by scrubbing; such contaminants in flue gases result when organo-chlorine compounds are present in the waste oil.

An important new development for incinerators uses the principle of particle fluidization; such units frequently are termed fluidized bed reactors. Figure 38 illustrates an integrated system for incineration of refinery oily and caustic wastes. This system uses both a cyclone to separate the solids and a scrubber to remove fines and acidic gases. The fluidized bed is predominantly sand kept in a state of suspension by means of the air forced into the bed.

Another type of fluidized bed incinerator is illustrated in Figure 39. This type of unit is reported to be suitable for incinerating waste oil or waste oil sludges bearing up to 18 percent inorganic material, 70 percent water and having heating values of 2,000 Btu/lb. When higher heating values are used, as in crankcase oils (15 to 20,000 Btu/lb.), the design is altered to include premixing of air and fuel (101).

Automotive waste oils may be used in conjunction with municipal incinerators as well (102). Mechanical atomizing burners, sonic and double vortex-type burners were evaluated. Mechanical and vortex units were found unsuitable while the sonic atomizer appears satisfactory.

The use of auxiliary firing using gas or fuel oil together with waste oils in commercial "Todd" burners has been reported to be efficient and capable of handling entrained water with little difficulty (103).

The deposition of slag on tubes and hearths of heating furnaces or boilers when burning high-ash waste oils has been reported. Fuel additives to retard slagging and tube fouling are commercially available (104); however the efficiency of these additives when used with waste oils has not been determined.

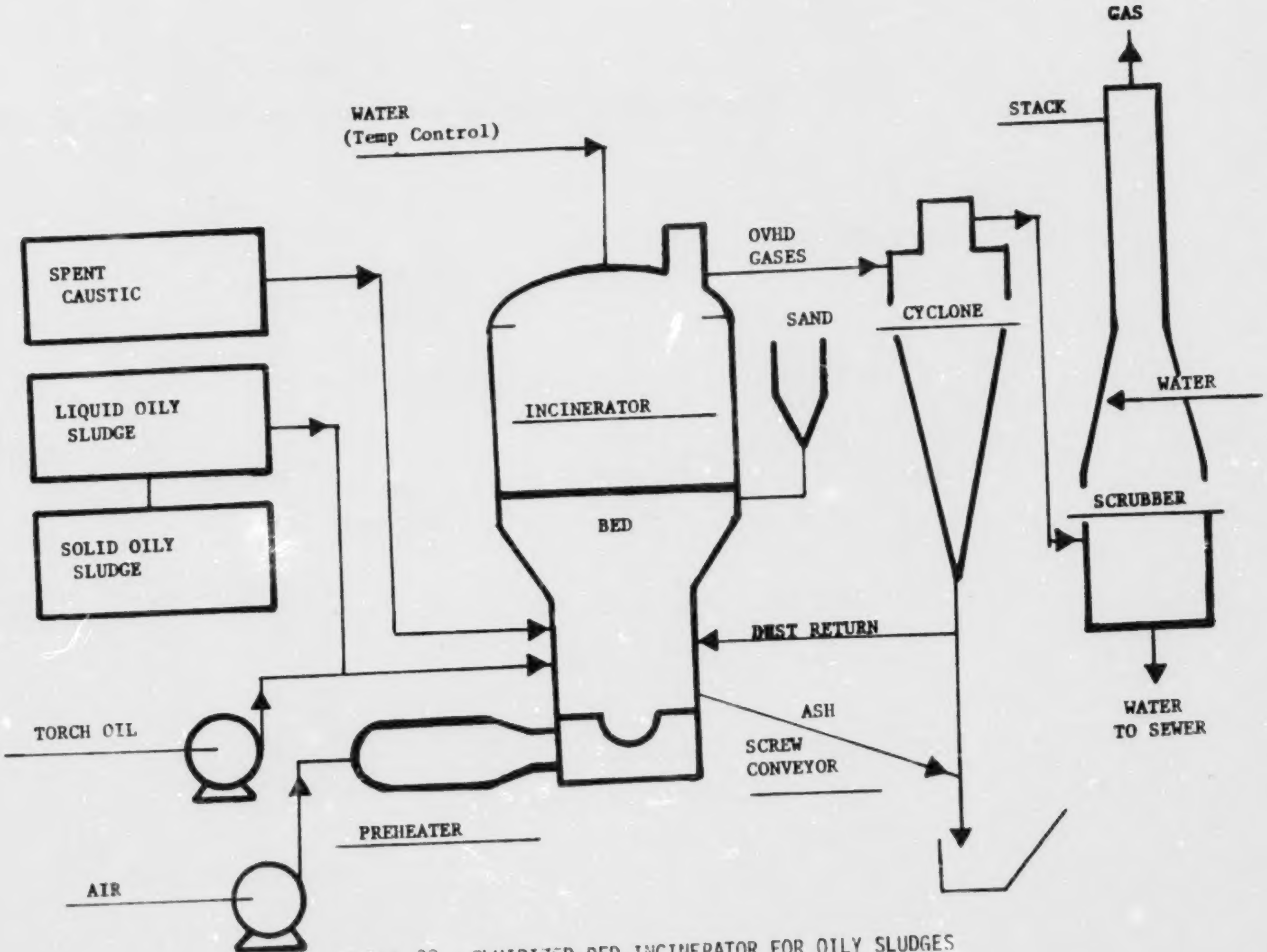

GAS
STACK
WATER
(Temp Control)
OVHD
GASES
CYCLONE
SPENT
CAUSTIC
SAND
INCINERATOR
WATER
LIQUID OILY
SLUDGE
SCRUBBER
BED
SOLID OILY
SLUDGE
DUST RETURN
WATER
TO SEWER
ASH
TORCH OIL
SCREW
CONVEYOR
PREHEATER
AIR

FIGURE 38. FLUIDIZED BED INCINERATOR FOR OILY SLUDGES

(Ref. 100)

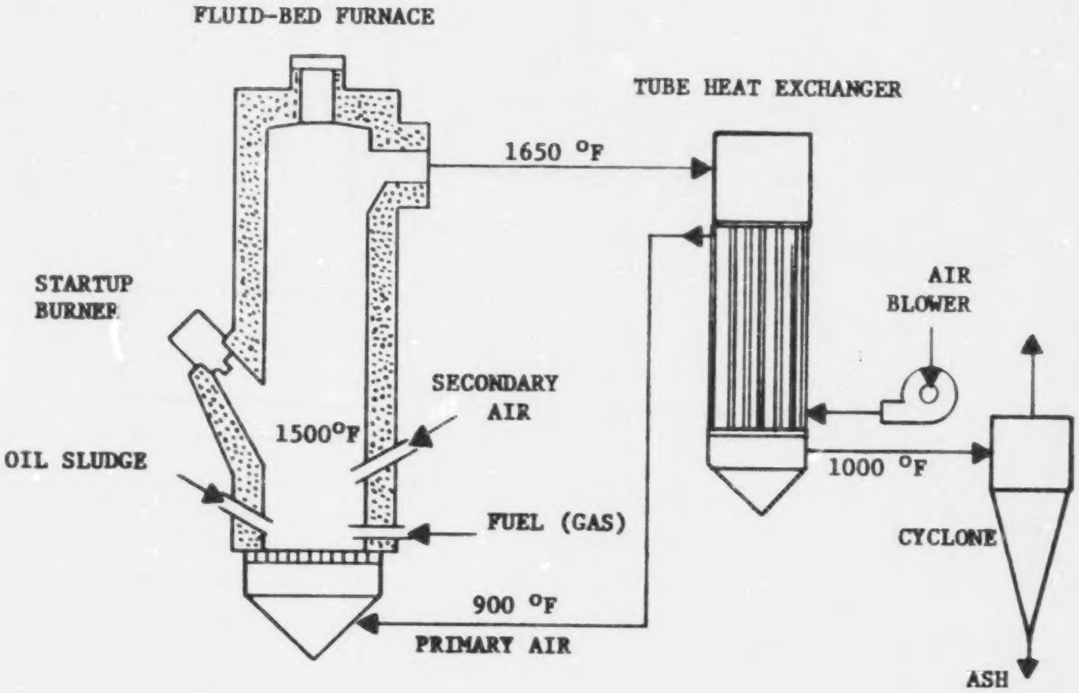

FLUID-BED FURNACE
TUBE HEAT EXCHANGER
1650 °F
STARTUP BURNER
AIR BLOWER
SECONDARY AIR
1500°F
OIL SLUDGE
1000 °F
FUEL (GAS)
CYCLONE
900 °F
PRIMARY AIR
ASH

FIGURE 39. FLUIDIZED BED COMBUSTION OF REFINERY WASTE SLUDGE.

(Ref. 101)

The use of waste oils, particularly crankcase oils for use as fuel to be blended with other fuels, is receiving wider attention. Currently, tests in the Baltimore area (105) are being evaluated. In this large scale test, one percent of waste oil is being blended with heavy fuel and burned to evaluate combustion characteristics and lead fallout. Blending is done in a ratio of 99 parts No. 5 or No. 6 fuel oil with one part waste oil. Target lead concentrations for air quality control are less than 1μ gram Pb/$M^3$. Satisfactory incineration of 300 gph of waste metalworking and crankcase oils using a commercial "Prenco" (106) incinerator (pyro-decomposition system) has been recorded by the State of Maryland (107).

The use of oil as a fuel for Portland cement manufacture has been debated frequently (108); however, low price is an important factor in cement manufacture, coal being the predominant fuel, where available. Large amounts of waste oil could be consumed in this manner since a single 6,000 barrel per day Portland cement plant uses about 6 x $10^9$ Btu/day equivalent to about 40,000 gpd waste oil. Assuming only 10 percent waste oil (the balance being coal) 1.25 x $10^6$ gals. per year of waste oil could be disposed of in this manner. Since cement kilns usually have air pollution control equipment, it is possible that no additional facilities would be necessary.

Oily sludges and other materials have been disposed of by dumping in the ocean. Liquid wastes frequently have been dumped beyond the three-mile continental limit either as containerized (drummed) waste or by bulk discharge from a barge (109, 110).

An indirect means of disposal is by use of waste oils as dust controllers, better known as road oils. Although road oils have been and still are manufactured as virgin petroleum materials, a large fraction of the material used in this category is waste crankcase oil. Road oiling is carried out by spraying dirt roads with oil by means of tanker-trucks equipped with drilled pipe spray headers. The amount used per mile of road depends on the nature of the specific job (111). The acceptability of this method of indirect disposal is moot since the application of oil to the land surface can result in pollution of aquifers and streams due to infiltration and runoff. The fate of metallic constituents such as lead, barium and zinc after road oiling is performed has not been documented. An estimated 100 million gals/year of oil are disposed of nationally by this method (112).

Ponding in unlined ponds has been used for oily waste disposal, however, such techniques cannot be considered acceptable in the current scene. The use of lined ponds for settling oil wastes for further processing may be acceptable in meteorologically safe areas and areas where odor is not a problem.

Sanitary landfilling has been used for waste oil disposal for both petroleum based waste (23) and animal or vegetable waste oils. Waste oils from food processing such as potato chip and similar production usually has a high melting point and frequently is disposed of as "solid waste" (113). Such material is considered to be completely biodegradable. The use of small amounts of waste petroleum based oil and oil sludges when admixed with other sanitary landfill has been practiced. The acceptability of this method has not been fully documented or demonstrated.

Land disposal of waste oil by means of bacterial degradation (114) has been reported. This is carried out by spreading the waste oil to a depth of six inches over a diked section of land; subsequently, the water in the waste material is permitted to drain and the remaining oil waste is mixed with six inches of soil by means of a bulldozer. This mixing is carried out several times per month for 90 to 270 days during which various bacteria degrade the oil. Pseudomonas species have been found to be the most numerous hydrocarbon oxidizers (115). Decomposition rates vary from five to 60 lbs. of oil per cubic foot of soil per month. High molecular weight, high viscosity and crystallinity have been observed to inhibit decomposition. In one operation (115) disposal was carried out using a soil with a pH of 4.4 to 4.8; limestone, nitrogen and phosphorus were added to the soil to enhance decomposition. A temperature of 86°F appeared optimum for this disposal method.

Biological degradation within the soil must be considered as acceptable only at specific sites since percolation of oils into aquifers and runoff into adjacent waterways must be considered a hazard in this respect.

Deepwell disposal has been practiced as a means of disposal of oil field wastes for many years (116). Disposal into subsurface formations including sandstones, limestone and unconsolidated brine sands have been practiced for many petrochemical wastes. However, waste crankcase oil or other predominantly oily waste generally is not disposed of by deepwell injection since the extensive pretreatment required for the waste oil prior to injection makes the oil suitable for disposal by more economical means. Injection wells for aqueous wastes generally are deep, ranging up to 12,000 feet, although some may be as shallow as a few hundred feet. This method of disposal requires thorough study of the surrounding geological formation and evaluation of its long-term suitability. Because of the high cost of drilling, equipping, maintaining and operating such wells, together with the controversial value of waste disposal wells, they do not appear to be recommended for waste oil disposal.

# SECTION XIV

## DISPOSAL OF RESIDUES FROM TREATMENT PROCESSES

It is axiomatic that each re-refining or reprocessing system leads to the production of its own unique residue which in turn must be disposed of. Frequently the process waste disposal system overshadows the benefits produced by the primary process due to the production of toxic wastes, heated wastes, difficult-to-treat or refractory process wastes. It may be that the capital and operating costs associated with disposal of process residues may render a primary process uneconomical. Thus, it is germane to the consideration and selection of primary waste oil re-refining or reclamation processes to evaluate the complexity, operability, reliability, economics and environmental impact of the process residue disposal system.

Each of the processes described in Sections XI, XII and XIII is accompanied by the production of some process wastes. These cover the gamut of wastes including solid, liquid and airborne materials of organic, inorganic and biological composition. Additionally, many of these processes require considerable amounts of thermal energy and electrical energy thus leading to the production of large quantities of waste heat. Although much of the latter may be rejected to the atmosphere, appreciable quantities of thermal waste may be rejected to the waterways adding to the waste heat load being absorbed by rivers, lakes, estuaries and oceans.

As a means of carrying out a primary evaluation of residue disposal systems and potential problems, it is useful to chart the inter-relationship of waste oil re-refining or direct disposal processes, with residue type, ultimate disposal method and process description. The results of this approach are shown in Table 33. For each of the specific primary processes selected, it is clear that some waste disposal system must be selected and that the waste disposal systems for the acid-clay or caustic soda-clay processes produce a significant quantity of residue.

TABLE 33

WASTE OIL RE-REFINING PROCESS RESIDUE DISPOSAL

| Primary Process Type | Solid Waste Description | Liquid Waste Description | Airborne Waste | Thermal Waste | Critical Factors | Method of Disposal |
|---|---|---|---|---|---|---|
| Gravity separation or decanting of oil-water mixtures | metallic wear particles and mineral trash | oil-contaminated water, variable concentration | -- | minor if heating used to assist process | separability of oil-water mixture | solids to landfill; water to receiving body after treatment |
| Distillation of waste crankcase oils | coke & sludge from still bottoms & tube furnaces. Metallic content of still bottoms | hydrocarbon-contaminated decanted water; cooling tower blowdown | ejector vents, cooling tower drift | latent heat of condensed stream | heavy metal content of still bottoms; tower blowdown or decanter wastewater hydrocarbon content | solids to landfill; water to receiving body; vents and drift to atmosphere; latent heat to air or receiving bodies |
| Extractive purification of waste oils using solvents (propane or phenol, or dichloroethylether) | metallic still bottoms and sludge | as above, plus solvents such as phenol in wastewater | ejector vents, tower drift, volatile solvents such as propane or acetone | latent heat of condensed streams | heavy metals with crankcase oil feeds; tower blowdown; hydrocarbon content in effluent; type of hydrocarbon | as above |

TABLE 33 (Continued)

WASTE OIL RE-REFINING PROCESS RESIDUE DISPOSAL

| Primary Process Type | Solid Waste Description | Liquid Waste Description | Airborne Waste | Thermal Waste | Critical Factors | Method of Disposal |
|---|---|---|---|---|---|---|
| Caustic soda-demulsifier, clay settling, centrifuging, adsorption and distillation | metallic wear particles & mineral trash; spent oil-laden clay; heavy metal sludges | aqueous caustic soda; additive solutions & slurries; centrifuge sludge | tower drift | latent heat of distilled oils | heavy metals content | neutralization & disposal to receiving body; solids to landfill or incinerator; sludges to landfill or incinerator |
| Acid-clay distillation | spent clay-oil cake; still bottoms sludge | oil-contaminated decanted water; sulfuric acid-oil sludge | ejector vents | latent heat | sulfuric acid waste; waste clay | clay to landfill or incineration; acid sludge to lagoons & ponds; oil-bearing water to receiving bodies |
| Filtration | sludge, spent filter aid, discarded media | filtrate residues from startup | -- | -- | spent filter aid; used cloths or paper | solids to landfill; liquids to incinerator |
| Centrifuging | sludge | oil-contaminated water | -- | -- | sludge composition; hydrocarbon-in-water concentration | sludge to ponds, lagoons or landfill; water to receiving bodies after treatment |

## TABLE 33 (Continued)

## WASTE OIL RE-REFINING PROCESS RESIDUE DISPOSAL

| Primary Process Type | Solid Waste Description | Liquid Waste Description | Airborne Waste | Thermal Waste | Critical Factors | Method of Disposal |
|---|---|---|---|---|---|---|
| Incineration | ash | scrubber blowdown | scrubber plume or particulates not removed from stack discharge | water wall and scrubber waste heat | Pb content; stability of ash | solids to landfill |
| Combustion as fuel | ash | boiler blowdown | particulates | -- | airborne heavy metals, Pb, Zn, Ba etc. | solids to landfill |
| Deepwell disposal | filter sludge & cake | treatment solutions, settled water | -- | -- | combined process wastes | solids to landfill |
| Landfill | unreacted materials | percolating water or runoff | odor bodies; flammable vapor | -- | runoff & percolation | water to aquifers & receiving bodies |
| Hydrocarbon-to-protein | process sludges; off spec. product | unreacted feed | vent gases | -- | -- | solids & liquids to incineration |

TABLE 33 (Continued)

WASTE OIL RE-REFINING PROCESS RESIDUE DISPOSAL

| Primary Process Type | Solid Waste Description | Liquid Waste Description | Airborne Waste | Thermal Waste | Critical Factors | Method of Disposal |
|---|---|---|---|---|---|---|
| Hydrotreating-cracking-and refining | spent catalyst, still bottoms, cakes | cooling tower blowdown | vent & purge gases | latent heat | -- | solids to metal (catalyst) reclamation or landfill; gases to atmosphere |

# SECTION XV

## PLANT DESIGN AND OPERATION

Currently operating re-refining plants appear to be located close to large metropolitan areas (see Section XXII). Generally, the selection of sites for these plants are governed by local zoning ordinances, the availability of disposal sites (for process wastes) and proximity to the sources of waste oil supply and product demand. There are few data describing re-refining plant design and operation.

The skill levels necessary to operate waste oil re-refining operations are similar to those found generally in the petroleum process industry. However, variability in the composition of the feedstock for these plants makes processing a "fine art" and requires a thorough understanding of the delicate balance between feed, process controls, costs and end product characteristics.

The reliability of the clay-acid distillation plant is impaired by frequent corrosion, particularly in overhead piping and condensers (66). Distillation plants using flash heaters have experienced coking, tar deposition and plugging of process lines, columns and pumps (38). Waste oil pumping has proved to be a source of maintenance problems, and one operator has tested 8 different types of pumps (111) but is not yet satisfied with the results. Vane-type and gear-type rotary positive displacement pumps have not yielded good service life in waste crankcase oil pumping. "Moyno" type pumps are being tested currently and are expected to give good service for handling the bottoms product from distillation operations (117).

Control of process waste disposal such as acid sludge, clay and tars has proven difficult in several ~~locations.~~ Some plants discharge their wastes to pits while others use lagoons or ponds. However, rupture of dikes or flooding has caused the dispersal of process waste in at least one case.

Equipment cleanup, rodding out, air blowing, steam blowing, solvent washing and similar measures are frequently required to maintain process throughputs.

Detailed design data on waste oil re-refining plants has not appeared in the literature. Personal interviews with operators has not revealed any significant design data at this time. Because of the marginal nature of re-refining and historical factors surrounding the growth of this type of enterprise, many re-refiners are known to purchase used equipment whenever possible (118) to reduce the cost of capital expenditure. This approach, in general, would tend to aggravate the overall problem of maintenance.

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## SECTION XVI

## TRANSPORT SYSTEM DESIGN AND OPERATION

Interviews with area waste oil operators indicate that many of the pickups are performed on an ad-hoc basis, usually by telephone, on an arrangement made for a specific time. One operator (111) working with a small fleet of radio-equipped trucks is able to dispatch his equipment from source to source and from source to disposal site without returning to the main "depot" until the end of a shift. Most of these trucks are small, ranging from 2,000 to 3,000 gallons, although larger units, up to 7,800 gallons, are used for long hauls to re-refiners.

The life of these smaller tanktrucks has been reported as 10 years. Some tankers are equipped with sight glasses which permit visual inspection of the charge as it is pumped aboard.

Standard tanker equipment includes gas and diesel rigs with a waste oil capacity (based on 7.5 lbs/gal) of 4,200, 5,700, 6,000, 9,400 and 14,000 gallons(119). These units would be classified as: 3-axle combination gas, 3-axle combination diesel, 4-axle combination gas, 5-axle combination diesel and 5-axle twin-haul combination diesel rigs, respectively. Drivers of this equipment are termed "city drivers" if all hauling is done within a metropolitan area and "line drivers" if they are intercity. This terminology is important in computing the costs of hauling, as will be covered in a later section.

Standard tanktrucks must be fitted with pumping equipment, transfer lines and hoses suitable for the intended service.

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# SECTION XVII

## PLANT, CAPITAL, OPERATING AND MAINTENANCE COSTS

The majority of cost data published in the literature or available by personal communication covers the acid-clay-distillation plant, and in one case, a straight distillation plant.

For the plants described by Hartung ( Table 34) employing distillation, centrifuging, settling and clay treatment, cost values are shown in Table 34. These are based on a 6 day/week operation using waste crankcase oil feed. The smallest economical size is estimated to be 3,000 gpd. It is interesting to note that considerably more process equipment is needed to make lube oil rather than fuel oil. Analysis of the capital cost data indicates a fair degree of optimism since the exponential scaling factor relating the size ratio is about 0.52. Small plants of this type have been noted to have scaling factors closer to 0.7. The fixed charges assigned to oil costs should be larger than shown.

The results of process analyses using different sequences of re-refining waste oil are shown in Tables 35 through 41. The "A" and "B" processes compared here differ as shown in Table 42; note that only the processing sequence differs between A and B, the actual unit operations are the same. This study was performed by Dr. W. H. Wood as noted in the reference (66). These data were prepared around 1962, thus, for current use, they should be increased by at least 50 percent on the basis of inflationary rises over the period 1962-72.

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## TABLE 34

## PROJECTED* CAPITAL COST OF OIL RE-REFINING PLANTS

(Ref. 80)

| Size (gals. per year) | Lubrication Grade | | Fuel Oil Grade | |
|---|---|---|---|---|
| | $Plant Cost | Oil Cost, ¢/gal. | $Plant Cost | Oil Cost,¢/gal. |
| 500,000 | 84,000 | 13.0 | 52,000 | 10.0 |
| 1,000,000 | 120,000 | 9.6 | 72,000 | 7.3 |
| 2,000,000 | 175,000 | 7.8 | 100,000 | 5.4 |
| 5,000,000 | 280,000 | 6.3 | 152,000 | 3.8 |
| 10,000,000 | 400,000 | 5.6 | 210,000 | 3.1 |

* Estimated in 1969

## TABLE 35

## ACID-CLAY COST COMPARISON - METHOD A vs METHOD B

| Method A | Method B |
|---|---|
| 1040 gal.waste oil | 1040 gal.waste oil |
| ↓ | ↓ |
| Dehydrate (300°F) | Dehydrate & Distill (20% O.H. @ 575°F) |
| ↓ | ↓ |
| 1000 gal. dehydrated oil | 800 gal. stripped oil |
| ↓ | ↓ |
| Acid Treat (2%) (20 gal. acid) - $ 3.30 | Acid Treat (2%) (16 gal. acid)- - - $ 2.64 |
| ↓ | ↓ |
| 900 gal. Acid-Treated Oil | 720 gal. Acid-Treated Oil |
| ↓ | ↓ |
| Clay Contact & Distill<br>(270 lb F.E.)<br>(20% O.H. @ 575°F)- - - - - $ 4.73 | Clay Contact (315°F)<br>(216 lb F.E.)- - - - - - - - - - $ 3.78 |
| ↓ | ↓<br>↓ |
| 720 gal. before filtering | Filter |
| ↓ | ↓ |
| Filter | ↓ |
| ↓ | ↓ |
| 711 gal. finished oil- - - - - - - - $ 8.03 | 712 gal. finished oil- - - - - - - - - $ 6.42 |
| Cost, $/M gal. finished oil- - - - - - -$11.29 | Cost, $/M gal. finished oil- - - - - - -$ 9.02 |

| Delivered Costs: | Acid | 16.5¢/gal. |
|---|---|---|
| | F.E. | $35/ton |

## TABLE 35 (Continued)

## ACID-CLAY COST COMPARISON - METHOD A vs METHOD B

### EXPERIMENTAL DATA

### Method A

| % Acid Treat | Clay | Lb/Gal. | Temp °F | % O.H. | ASTM Color | TAN | SUS @ 210°F |
|---|---|---|---|---|---|---|---|
| 3.0 | AAC | 0.3 | 555 | 25 | 4.0* | .40 | 56.1 |

* Very poor color stability and high TAN

### Method B

Pre-distilled to 25% O.H. at 555°F

| % Acid Treat | Clay | Lb/Gal. | Temp °F | ASTM Color | TAN | SUS @ 210°F |
|---|---|---|---|---|---|---|
| 3.0 | F.E. | 0.3 | 310 | 4.0 | .05 | 55.9 |

Note: Approximately 10% loss of oil to sludge in both cases.

TABLE 36

## ACID-CLAY COST COMPARISON - METHOD A vs METHOD B

(assume 4% water)

| Method A | Method B |
|---|---|
| 1040 gal. waste oil | 1040 gal. waste oil |
| ↓ | ↓ |
| dehydrate (310°F) | dehydrate & distill |
| ↓ | ↓ (25% O.H. dist @ 555°F) |
| ↓ | ↓ |
| 1000 gal. dehyd. oil | 750 gal. stripped oil |
| ↓ | ↓ |
| acid treat (3%) | acid treat (3%) |
| ↓ (30 gal. acid) - - - - -$4.95 | ↓ (22.5 gal. acid)- - - - -$3.72 |
| ↓ | ↓ |
| clay contact & distill | 675 gal. acid-treated oil |
| ↓ (270 lb. AAC) - - - - - $9.19 | ↓ |
| ↓ (25% O.H. dist @ | clay contact (202.5 lb. F.E. |
| ↓ 550°F) | ↓ @ 310°F)- - - - - - - - -$3.44 |
| ↓ | ↓ |
| 675 gal. oil before filtering | filter |
| ↓ | ↓ |
| filter | ↓ |
| ↓ | ↓ |
| 669 gal. finished oil- - - - - -$14.14 | 668 gal. finished oil- - - - - - -$7.16 |
| Cost in $/M gal fin. oil- - - - - $21.14 | Cost in $/M gal. fin. oil- - - - - $10.72 |

| Delivered prices: | | |
|---|---|---|
| | Acid - - - - - - - - - - | 16.5¢/gal. |
| | F.E. - - - - - - - - - - | $34/ton |
| | AAC - - - - - - - - - - | $68/ton |

## TABLE 37

Plant dehydrated sample from continuously operated unit at 275°F. Water content as received - 0.05%. Refiner desires 56 SUS @ 210°F viscosity and an ASTM color of about 4.5.

### METHOD A

All clay contacts run to 25% overhead distillate at 555°F for 56 sec. vis.

| % Acid Treat | Clay | Lb/Gal. | ASTM Color | Color Stab. | TAN* | AcOH** | Acid-Clay Costs, $/M gal. fin. oil |
|---|---|---|---|---|---|---|---|
| 2 | F.E. | 0.3 | 6.0 | poor | .27 | 7.5 | 11.91 |
| 2 | F.E. | 0.4 | 4.75 | fair | .09 | 7.5 | 14.35 |
| 2 | F.E. | 0.5 | 4.5 | good | .07 | 7.0 | 16.81 |
| 2 | AAC | 0.2 | 7.0 | poor | .46 | 13.2 | 14.81 |
| 2 | AAC | 0.3 | 4.5 | poor | .42 | 12.6 | 18.93 |
| 2 | AAC & F.E. (50/50) | 0.3 | 5.5 | poor | .40 | 10.2 | 15.41 |
| 3 | F.E. | 0.3 | 5.5 | poor | .22 | 12.6 | 14.33 |
| 3 | F.E. | 0.4 | 4.75 | fair | .13 | 11.6 | 16.77 |
| 3 | F.E. | 0.5 | 4.5 | good | .05 | 10.2 | 19.24 |
| 3 | AAC | 0.2 | 5.5 | poor | .38 | 14.1 | 16.56 |
| 3 | AAC | 0.3 | 4.0 | poor | .40 | 14.2 | 21.33 |
| 3 | AAC & F.E. (50/50) | 0.3 | 4.0 | fair | .21 | 11.0 | 17.81 |

* Total Acid Number

** Acidic Overhead (Distillate)

## TABLE 37 (Continued)

### Method B

| % Acid Treat | Clay | Lb/Gal. | ASTM Color | Color Stab. | TAN* | AcOH** | Acid-Clay Costs, $/M gal. fin. oil |
|---|---|---|---|---|---|---|---|
| 2 | F.E. | 0.2 | 4.75 | fair | .13 | 4.0 | 7.10 |
| 2 | F.E. | 0.3 | 4.5 | good | .04 | 2.7 | 8.89 |
| 2 | F.E. | 0.4 | 4.25 | excel. | .03 | 2.5 | 10.71 |
| 3 | F.E. | 0.2 | 4.5 | good | .08 | 3.1 | 8.90 |
| 3 | F.E. | 0.3 | 4.0 | good | .05 | 2.7 | 10.69 |
| 3 | F.E. | 0.4 | 3.75 | excel. | .03 | 2.3 | 12.51 |

* Total Acid Number

** Acidic Overhead (Distillate)

## TABLE 38

Plant dehydrated sample from continuous process operation at 260°F. Contained 0.08% water as received. Re-dehydrated in laboratory to 0% water.

Refiner desires 3-1/2 to 4 ASTM color with viscosity of about 56 SUS @ 210°F.

### Method A

All clay contacts run to 22% overhead distillate at 550°F for a 56 sec. vis.

| % Acid Treat | Clay | Lb/Gal. | ASTM Color | Color Stab. | TAN | AcOH | Acid-Clay Costs, $/M gal. fin. oil |
|---|---|---|---|---|---|---|---|
| 3.0 | F.E. | 0.3 | 4.25 | fair | .19 | 7.8 | 13.77 |
| 3.0 | F.E. | 0.4 | 4.0 | good | .08 | 6.7 | 16.11 |
| 3.0 | AAC | 0.3 | 3.5 | poor | .26 | 10.1 | 20.50 |
| 3.0 | AAC & F.E. (50/50) | 0.3 | 3.5 | fair | .21 | 8.0 | 17.12 |
| | | | | | | | |
| 2.7 | F.E. | 0.47 | 4.0 | good | .07 | -- | 17.18** |
| 2.7 | AAC & F.E. (50/50) | 0.37 | 4.0 | fair | (.15) | -- | 22.97** |

(Note: Acid number in parenthesis run by refiner)

** Plant run by refiner who furnished data. Except where noted, inspections of product made by this laboratory.

## TABLE 38 (Continued)

### Method B

Sample pre-distilled to 22% overhead at 575°F to give 56 sec. viscosity.
All clay contacts run for 15 minutes with steam at 310 to 325°F.

| % Acid Treat | Clay | Lb/Gal. | ASTM Color | Color Stab. | TAN | AcOH | Acid-Clay Costs, $/M gal. fin. oil |
|---|---|---|---|---|---|---|---|
| 3.0 | F.E. | 0.25 | 4.0 | excel. | .06 | 2.9 | 9.78 |
| 3.0 | F.E. | 0.3 | 3.75 | excel. | .04 | 2.7 | 10.71 |
| 3.0 | F.E. | 0.4 | 3.5 | excel. | .02 | 2.3 | 12.50 |

## TABLE 39

Sample of plant dehydrated waste oil in batch process at 250°F. Water content as received - 0.05%. This refiner desires about a 62 SUS oil @ 210°F at approximately a 4 ASTM color.

### Method A

All contacts run to 20% overhead distillate at 575°F for a 62 sec. vis.

| % Acid Treat | Clay | Lb/Gal. | ASTM Color | Color Stab. | TAN | AcOH | Clay-Acid Costs, $/M gal. fin. oil |
|---|---|---|---|---|---|---|---|
| 3.0 | F.E. | 0.2 | 3.75 | good | .06 | 6.0 | 11.13 |
| 3.0 | F.E. | 0.3 | 3.75 | excel. | .03 | 5.7 | 13.42 |
| 3.0 | F.E. | 0.25 | 3.75 | good | .05 | -- | 12.28** |
| 2.0 | AAC | 0.16 | 4.0 | poor | .13 | 7.6 | 9.14* |
| 2.0 | F.E. | 0.2 | 5.0 | good | .08 | 5.0 | 8.89 |
| 2.0 | F.E. | 0.25 | 3.75 | excel. | .04 | 4.7 | 10.03 |
| 2.0 | F.E. | 0.3 | 3.75 | excel. | .03 | 4.1 | 11.17 |

** Plant test by refiner who furnished data reported here. Notice close agreement with similar laboratory data.

* As compared to $13.59 when REFINER used 4% acid to overcome filtering problems.

TABLE 39 (Continued)

Method B

Pre-distilled to 20% overhead at 575°F to give 62 sec. vis.
All contacts run by steaming for 15 minutes at 310°F.

| % Acid Treat | Clay | Lb/Gal. | ASTM Color | Color Stab. | TAN | AcOH | Clay-Acid Costs, $/M gal. fin. oil |
|---|---|---|---|---|---|---|---|
| 2.0 | F.E. | 0.25 | 3.75 | excel. | .03 | 1.3 | 8.00 |
| 2.0 | F.E. | 0.3 | 3.75 | excel. | .02 | 0.9 | 8.90 |
| 2.0 | F.E. | 0.3 | 3.75 | excel. | .03 | -- | 8.90** |

** Plant test by refiner who furnished data reported here.
Notice close agreement with similar laboratory data.

## TABLE 40

This re-refiner has been using Method B (low temperature contact method) for many years. The sample as received had been steam stripped to about 610°F and contained no water.

### Method B

All clay contacts were made by steaming for 15 minutes at 300°F giving a product having a viscosity of 59 SUS @ 210°F.

| % Acid Treat | Clay | Lb/Gal. | ASTM Color | Color Stab. | TAN | AcOH | Acid-Clay Costs, $/M gal. fin. oil |
|---|---|---|---|---|---|---|---|
| 2.0 | F.E. | 0.2 | 4.5 | excel. | .05 | 2.3 | 7.11 |
| 2.0 | F.E. | 0.3 | 4.25 | excel. | .05 | 1.9 | 8.91 |
| 2.0 | F.E. | 0.4 | 4.0 | excel. | .04 | 1.1 | 10.71 |
| 2.0 | F.E. | 0.4 | 4.25 | excel. | .03 | -- | 10.71** |
| 3.0 | F.E. | 0.1 | 5.0 | fair | .14 | 3.5 | 7.11 |
| 3.0 | F.E. | 0.2 | 3.75 | good | .07 | 1.9 | 8.90 |
| 3.0 | F.E. | 0.2 | 3.75 | excel. | .05 | -- | 8.90**** |

** Represents normal plant operation. Data furnished by refiner.

**** Special test run made by refiner to check laboratory data.

Refiner states he has little acid corrosion of equipment. Has not replaced overhead piping and condensing equipment more than twice in last 10 years.

TABLE 41

This refiner has been using Method B (low temperature contacting method) for many years. The sample as received had been stripped of light distillate by continuous vacuum distillation prior to acid treatment. It contained no water.

Method B

All clay contacts were made by steaming for 15 minutes @ 350°F. All products had a viscosity of 57 SUS @ 210°F (plus or minus 0.2 seconds).

| % Acid Treat | Clay | Lb/Gal. | ASTM Color | Color Stab. | TAN | Clay-Acid Costs, \$/M gal. fin. oil |
|---|---|---|---|---|---|---|
| 3.0 | F.E. | 0.25 | 4.5 | good | .05 | 9.66 |
| 3.0 | F.E. | 0.3 | 4.25 | excel. | .03 | 10.55 |
| 3.0 | F.E. | 0.4 | 4.0 | excel. | .02 | 12.31 |
| 3.0 | AAC | 0.3 | 5.5 | poor | .15 | 15.35 |
| 3.0 | F.E. | 0.3 | 4.25 | excel. | .02 | 10.55** |

** This latter run is actual plant data furnished by the re-refiner. Notice the excellent comparison with the second laboratory test.

## TABLE 42

## DIFFERENCE IN OPERATIONAL PROCEDURE BETWEEN METHOD A AND METHOD B

| General Process Steps | Method A<br>High Temperature Contacting Method | Method B<br>Low Temperature Contacting Method |
|---|---|---|
| Dehydration | Dehydration<br>(250-350°F) | Combined Dehydration<br>& Distillation<br>(550-600°F) |
| ↓ | ↓ | ↓ |
| Acid Treatment | Acid Treatment | Acid Treatment |
| ↓ | ↓ | ↓ |
| Clay Contacting | Combined clay contacting<br>& distillation<br>(550-600°F) | Clay contacting<br>(300-350°F) |
| ↓ | ↓ | ↓ |
| Filtering | Filtering | Filtering |

It will be noticed that approximately the same temperatures are employed by both methods and the same number of steps. The only alteration is in the order of applying the different steps.

## TABLE 42 (Continued)

### EXPERIMENTAL DATA

### Method A

| % Acid Treat | Clay | Lb/Gal. | Temp. | % O.H. | ASTM Color | TAN | SUS @ 210°F |
|---|---|---|---|---|---|---|---|
| 2 | F.E. | 0.3 | 575 | 20 | 3.75 | .04 | 61.9 |

### Method B

Pre-distilled to 20% O.H. @ 575°F

| % Acid Treat | Clay | Lb/Gal. | Temp. | ASTM Color | TAN | SUS @ 210°F |
|---|---|---|---|---|---|---|
| 2 | F.E. | 0.3 | 315 | 3.75 | .02 | 62.0 |

Note: Approximately 10% oil lost to sludge in each case.

# SECTION XVIII

## TRANSPORT SYSTEM OPERATING AND MAINTENANCE COSTS

The cost of standard trucking equipment is shown in Table 43. Although it is unlikely that the first category - pickup trucks - would be used, they may be applied for small or short hauls.

A general rule-of-thumb for bulk transport cost is 60 percent labor, 10 percent operation and maintenance and 30 percent amortization.

Straight-time hourly earnings for trucking operations are shown in Table 44 for some selected areas in the U.S. (123).

The immediate outlook in the Washington, D.C. - Baltimore area is for wages to rise to the level shown in Table 45. On this basis, it should be anticipated that the cost of oil disposal will increase proportionately. An analysis of carrier expenses for intercity common carriers is shown in Table 46.

Current practices for waste oil hauling are variable. In some instances operators pick up oil at no cost; in others, the cost may be 2-3¢/gal.; while in still other cases there is a flat charge of $17.00 to $25.00 per load (usually under 1,500 gallons) as determined by local telephone interview.

In a contractual arrangement in the metropolitan Washington, D.C. area, the Defense Supply Agency, Property Disposal Office, received 2.25¢/gal. for waste crankcase oil (128). Oil at this location is stored in 25,000 gallon tanks enabling pickup by large over-the-road tankers in lots of 6,000 gallons.

There are few published data on the cost of operating and monitoring waste oil transport equipment.

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## TABLE 43

## COST OF TANK TRUCKS
(Ref. 122)

| | VEHICLE TYPE | FUEL TYPE | MAXIMUM CAPACITY LBS. | CAPACITY* GAL. | NET ACTUAL GAL. a) | UNIT COST OF EQUIPMENT b) $ |
|---|---|---|---|---|---|---|
| 1) | Pickup Truck | gas | 5,000 | 800 | 525 | 4,000 |
| 2) | 3-Axle Combination | gas | 40,000 | 5,500 | 4,200 | 10,000** |
| 3) | 3-Axle Combination | diesel | 45,000 | 7,400 | 5,700 | 12,000** |
| 4) | 4-Axle Combination | gas | 55,000 | 7,800 | 6,000 | 14,000 |
| 5) | 5-Axle Combination | diesel | 72,000 | 12,200 | 9,400 | 17,500** |
| 6) | 5-Axle Twin-Haul Comb. | diesel | 72,000 | 18,200 | 14,000 | 22,500*** |

NOTE that poundage may be met before actual volume; given enough time for the inquiry, manufacturers can provide cost of optimum design.

* Assumes 30 percent over-capacity for expansion and anticipated changes in regulations

** Interpolation (rule of thumb) from ATA, Inc.

*** Maximum additional cost for flexibility of use and construction @ 35 percent

a) Based on 7.45 gal/ft$^3$ of waste oil/gas/water mixture

b) Trucks and trailers, all necessary fittings on trucks; excludes loading/unloading equipment, accessories external to the truck and other necessary modifications

TABLE 44
(Ref. 123)

## AREA WAGE SURVEYS

August-September 1971

### TABLE A
### AVERAGE STRAIGHT TIME HOURLY EARNINGS FOR SELECTED TRUCKING OCCUPATIONS

| Selected Occupations | Omaha Nebraska | Chattanooga Tennessee | San Jose Calif. | Baltimore Maryland | Cleveland Ohio |
|---|---|---|---|---|---|
| Truck Drivers | 3.93 | 3.24 | 5.32 | 3.97 | 4.59 |
| Light (under 1½ tons) | 3.00 | 2.55 | 3.96 | 3.48 | 3.49 |
| Medium (1½ to 4 tons) | 4.08 | 3.22 | 5.28 | 3.53 | 4.44 |
| Heavy (over 4 tons) | 4.21 | 3.25 | 5.22 | 4.45 | 4.96 |
| Other than trailer | 3.94 | ---- | 5.64 | 3.97 | 4.70 |
| Fork Lift Operators | 3.70 | 2.89 | 4.12 | 3.81 | 3.94 |
| Laborers, Material Handling | 3.44 | 2.77 | 3.48 | 3.37 | 3.60 |
| Mechanics, Automotive | 4.33 | 3.65 | 5.14 | 4.28 | 4.72 |
| Shipping and Receiving Clerks | 3.16 | --- | 3.70 | 3.66 | 3.91 |

### TABLE B
### AVERAGE WEEKLY EARNINGS FOR SELECTED OFFICE AND CLERICAL OCCUPATIONS

| Selected Occupations | Omaha Nebraska | Chattanooga Tennessee | San Jose Calif. | Baltimore Maryland | Cleveland Ohio |
|---|---|---|---|---|---|
| Billing Machine Operators | --- | 91.00 | --- | 104.00 | 104.50 |
| Bookkeeping Machine Operators: | | | | | |
| Class A | 109.00 | 109.00 | 138.00 | 114.00 | 124.00 |
| Class B | 89.50 | 87.50 | 117.50 | 108.50 | 106.50 |
| Accounting Clerks: | | | | | |
| Class A | 128.00 | 124.00 | 140.00 | 139.50 | 144.50 |
| Class B | 100.50 | 96.00 | 117.00 | 109.50 | 108.50 |
| File Clerks: | | | | | |
| Class A | 112.00 | 93.00 | 118.50 | 127.50 | 118.00 |
| Class B | 95.50 | 83.00 | 102.50 | 94.50 | 97.00 |
| Class C | 73.00 | 71.50 | 94.00 | 83.00 | 81.00 |
| Order Clerks | 109.00 | 108.00 | 168.50 | 117.00 | 123.00 |
| Payroll Clerks | 127.00 | 109.50 | 139.50 | 143.00 | 129.50 |
| Comptometer Operators | 112.00 | --- | --- | 109.00 | 113.00 |
| Keypunch Operators: | | | | | |
| Class A | 117.50 | 100.00 | 138.00 | 123.50 | 121.00 |
| Class B | 93.50 | 88.00 | 124.50 | 109.50 | 112.50 |
| Secretaries, General | 127.00 | 118.50 | 153.00 | 135.50 | 143.50 |
| Switchboard Operators: | | | | | |
| Class A | --- | 106.50 | 126.50 | 117.00 | 130.00 |
| Class B | 86.50 | 125.00 | 112.00 | 101.50 | 106.50 |
| Tabulating Machine Operators: | | | | | |
| Class A | --- | --- | --- | 165.50 | 164.00 |
| Class B | --- | 129.00 | --- | 138.50 | 133.00 |
| Class C | --- | --- | - - - | --- | 116.00 |
| Typists: | | | | | |
| Class A | 102.50 | 96.00 | 136.00 | 110.50 | 118.00 |
| Class B | 81.50 | 85.50 | 109.50 | 94.50 | 97.50 |

Source: U. S. Bureau of Labor Statistics

## TABLE 45

## PROJECTED TRUCKING WAGE RATES

(Ref. 125)

| | City Driver | | Line Driver | |
|---|---|---|---|---|
| | Current | 01/73 | Current | 01/73 |
| Hourly Wage | $ 5.58 | $ 5.78 | $ 5.55 | $ 5.75 |
| Health & Welfare | .31 | .34 | .31 | .34 |
| Pension | .32 | .35 | .32 | .35 |
| TOTAL | $ 6.21 | $ 6.47 | $ 6.18 | $ 6.44 |

## TABLE 46

## MOTOR CARRIERS EXPENSE ANALYSIS
(Ref. 124)

| MOTOR CARRIER EXPENSE ANALYSIS, Class 1 intercity common carriers of general freight<br>Composite Expense Sheet - Year End 1970 | Average Expense Per Intercity Vehicle Mile (in cents) | Average Expense Per Intercity Ton (in dollars) |
|---|---|---|
| EQUIPMENT MAINTENANCE | | |
| Repairs & servicing - revenue equipment | 7.6 | 2.13 |
| Tires and tubes - revenut equipment | 1.0 | 0.54 |
| Other maintenance expenses | 1.8 | 0.49 |
| Total Equipment Maintenance | 11.3 | 3.16 |
| TRANSPORTATION | | |
| Drivers and helpers | 33.0 | 9.26 |
| Fuel and oil - revenue equipment | 3.0 | 0.84 |
| Purchased transportation | 10.3 | 2.90 |
| Other transportation | 7.0 | 1.95 |
| Total Transportation | 53.3 | 14.95 |
| TERMINAL | | |
| Supervision, office & other expenses | 6.2 | 1.73 |
| Salaries & wages - platform & other terminal employees | 12.5 | 3.50 |
| Other terminal expenses | 7.0 | 1.96 |
| Total Terminal | 25.7 | 7.19 |
| TRAFFIC | | |
| Supervision, office & other expenses | 2.2 | 0.62 |
| Tariffs and schedules | 0.2 | 0.05 |
| Other traffic expenses | 1.0 | 0.29 |
| Total Traffic | 3.4 | 0.96 |

## TABLE 46 (Continued)

## MOTOR CARRIERS EXPENSE ANALYSIS

| MOTOR CARRIER EXPENSE ANALYSIS, Class 1 intercity common carriers of general freight<br>Composite Expense Sheet - Year End 1970 | Average Expense Per Intercity Vehicle Mile (in cents) | Average Expense Per Intercity Ton (in dollars) |
|---|---|---|
| INSURANCE AND SAFETY | | |
| Public liability and property damage | 1.1 | 0.32 |
| Workmen's compensation | 0.9 | 0.25 |
| Cargo loss and damage | 2.3 | 0.63 |
| Other insurance and safety expenses | 1.0 | 0.29 |
| Total Insurance and Safety | 5.3 | 1.49 |
| ADMINISTRATIVE AND GENERAL | | |
| Supervision, office and other general office expenses | 3.2 | 0.90 |
| Communication service | 1.3 | 0.36 |
| Other general expenses | 3.3 | 0.91 |
| Total Administrative and General | 7.8 | 2.17 |
| Total Operation and Maintenance Expenses | 106.7 | 29.93 |
| OTHER EXPENSES | | |
| Depreciation expense-net, and amortization of carrier property | 4.9 | 1.37 |
| Operating taxes and licenses | 8.2 | 2.30 |
| TOTAL CARRIER OPERATING EXPENSES | 119.8 | 33.6 |

## TABLE 46 (Continued)

## MOTOR CARRIERS EXPENSE ANALYSIS

MOTOR CARRIER REVENUES AND EXPENSES 1950 - 1970:

| Per Intercity Vehicle Mile (in cents) | 1950 | 1955 | 1960 | 1965 | 1967 | 1968 | 1969 | 1970 |
|---|---|---|---|---|---|---|---|---|
| Average Total Operating Expenses[1] | 48.7 | 62.6 | 79.5 | 88.4 | 95.9 | 98.6 | 109.6 | 119.83 |
| Average Revenue[2] | 51.7 | 64.2 | 80.5 | 91.2 | 97.1 | 101.2 | 114.1 | 123.97 |
| **Per Intercity Ton (in dollars)** | | | | | | | | |
| Average Total Operating Expenses[1] | 14.07 | 17.76 | 23.94 | 23.63 | 26.03 | 26.80 | 29.92 | 33.60 |
| Average Revenue[2] | 14.95 | 18.19 | 24.25 | 24.37 | 26.36 | 27.51 | 31.17 | 34.76 |

---

[1] Components may not add to total due to rounding. Payments for net interest and income taxes come out of net revenue and are excluded from this analysis.

[2] Reflects freight revenue from intercity service only.

SOURCE: Based on latest available statistics from official reports of carriers to the Interstate Commerce Commission.

# SECTION XIX

## ACKNOWLEDGMENTS

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## SECTION XXI

## GLOSSARY OF TERMS

### Alkane

A saturated paraffinic hydrocarbon.

### Alkane Sulfonate

A substituted hydrocarbon in which one group is a sulfonic acid group or its salt (usually sodium salt). Used frequently as detergent stock.

### Aniline Number (or Point)

Temperature, in °C at which mixtures of petroleum and aniline become miscible. The value is a measure of sludge solvent power. The lower aniline point usually is associated with high solvent power.

### API

Degrees API. An American Petroleum Institute density scale used frequently for hydrocarbons. The equation is

$$^{\circ}\mathrm{API} = \frac{141.5}{\mathrm{S.G.}\,70^{\circ}\mathrm{F}/60^{\circ}\mathrm{F}} - 131.5$$

### Ash, Sulfate

A measure of metallic residue in petroleum products. ASTM test D-874-63 describes the method. The ash remaining after reaction with $H_2SO_4$ is calculated as weight percent sulfates.

### Asphaltenes

High molecular weight hydrocarbons of asphaltic nature. Insoluble in petroleum naphtha but soluble in benzene. Believed to be responsible for sludge and varnish deposits.

### Atomic Absorption

An analytical technique for determining composition of compounds and mixtures.

### Base Oil

See Base Stock.

GLOSSARY (continued)

Base Stock

Refined lubricating oil fractions usually produced from crude petroleum. One or more of these fractions are used in manufacturing finished lubricating oils.

Baume'

A density scale, expressed in degrees Baume' ($^{o}$Be'). For liquids heavier than water, specific gravity, SG, is related by the equation:

$$SG = \frac{145}{145 - {}^{o}Be}$$

Benzene Insoluble

A measure of a motor oil's tendency to break down during high temperature oxidative attack. ASTM Test No. D-893 describes the procedure. High values of benzene insolubles are undesirable.

Bright Stock

A heavy, high viscosity, but clear base oil. Usually used to increase the viscosity of a blended lubricating oil.

BS&W

Abbreviation for bottom settlings and water. Ordinarily found in petroleum crudes or undistilled fuels. Such impurities also are found in waste oils.

Blowby

Combustion products and air/fuel mixture leaking into the engine crankcase during operation.

Carcinogen

A chemical agent causing carcinoma (cancer).

C.C.R.

Abbreviation for Conradson Carbon Residue. A measure of a lube oil's tendency to produce varnish and sludge. Measured in weight percent.

## GLOSSARY (continued)

### Chromatography

A technique for separating mixtures fluids by virtue of differences in rates of migration of the fluid components in a packed column. Column packings of alumina,silica gel, activated carbon and other materials are used.

### Clay Treatment

Adsorptive purification of oils by contacting the oil to be purified with finely divided natural or synthetic mineral adsorbents ("clays").

### C.O.C.

Cleveland Open Cup, a type of flash point test in which liquid is heated in an open cup to measure temperature at which vapor ignites.

### Color, ASTM

A color comparison test using colored glass standards. Refer to ASTM tests D156 and D1500.

### Conradson Carbon Residue

See C.C.R.

### Centistoke

A unit of kinematic viscosity.

### Cracking

Process by which petroleum fractions are decomposed to produce fuels, oils and other products. Normally carried out at elevated temperature with and without the aid of a catalyst.

### Cs.

See Centistoke

### Cyclization

A thermo-catalytic process for producing ring-type compounds from straight or branch chain paraffin.

Detergent Additive

A material added to lubricating oils to hold in suspension oil-breakdown products formed in service. A more proper description of this additive function is "dispersant."

Disproportionation

A chemical reaction in which two molecules of the same material react to form both a lower and a higher molecular weight homolog. Catalysts plus heat are usually used in petrochemical processes.

Emission Spectroscopy

An analytical technique using the light emitted by an incandescent element to detect and characterize the element.

Engler Viscosity

A kinematic viscosity scale expressed in degrees, e.g., 2.3° Engler.

EP

Extreme pressure. Refers to additives put into oils for protection of surfaces with very high bearing loads.

Fuller's Earth

A naturally occurring adsorptive clay treated, ground and purified before use. Used for removal of color and odor bodies and acidic contaminants in oils.

Furol

Saybolt viscosity scale. Originally for heavy fuels and road oils.

Gasoline Dilution Test

A measure of unburned motor fuel in crankcase oil. Measured in percent volume using atmospheric steam distillation of a sample of oil.

GLOSSARY (continued)

Hydraulic Oil

Lubricating oil ranging in viscosity from about 150 SSU to about 2200 SSU at 100°F. Usually compounded with antifoam and anticorrosion additives. Used for hydraulic power and control systems, enclosed gears, circulating lubrication systems and similar systems.

Hydrogenation

Addition of hydrogen to an unsaturated hydrocarbon. Usually carried out in presence of catalyst and at elevated temperature and pressure.

Hydrogen Transfer

Shifting of atoms of hydrogen in a hydrocarbon molecule such that different compounds are formed.

Fractional Distillation

Separation of a mixture of liquids into lower-boiling and higher-boiling products. The process may be batch or continuous and may yield pure products or other mixtures with narrower boiling ranges than the original feed.

Hydrotreating.

A severe hydrogenation process for base oil stock production.

IBP

Abbreviation for Initial Boiling Point. Usually expressed as °F at 1 atmosphere.

Industrial Lube Oils

As classified by the U.S. Dept. of Commerce, these comprise marine, industrial and railroad oils intended primarily for lubrication purposes including oils for cutting operations.

Interfacial Tension

The force required to transfer a surface from one fluid phase to another. Expressed in dynes/cm and measured with a tensiometer. For oils, distilled water usually is used as the second fluid phase.

GLOSSARY (continued)

Isomerization

Restructuring of a molecule to produce a different compound without any change in the number of atoms. Usually requires the input of some form of energy to cause the change.

Mineral Oil

A "pure" base oil without any additives.

Molecular Sieve

Adsorbents of either natural but mostly synthetic mineral origin having well-defined properties and capable of adsorbing molecules of a specific size. May be used for separation of gas mixtures and as catalyst.

Neutralization Number (ASTM Test D974-64)

The number of milligrams of potassium hydroxide needed to neutralize 1.0 gram of oil sample.

NPA Color

A petroleum color scale originated by the National Petroleum Association. Now refined and referred to as the ASTM (Test No. D-1500) color. These range from <1 for light straw colors to 8 for dark reds.

Octane Number

A measure of a gasoline's tendency to pre-ignite (knock). Determined by comparing performance of an engine with the test fuel and then with mixtures of n-heptane and isooctane. The volume percent n-octane giving the same performance as the test fuel is the octane number.

Other Industrial Oils

A U.S. Dept. of Commerce designation. Products derived primarily from petroleum and having a viscosity of more than 45 SSU at 100°F and intended for non-lubricating use. Excludes solvents, asphalts, petrochemicals, etc.

Oxo Process

A hydroformylation reaction in which olefins are reacted with carbon monoxide and hydrogen to form aldehydes, alcohols and acids. Usually carried out in presence of a cobalt catalyst and at elevated pressure and moderate temperature.

GLOSSARY (continued)

Paraffinic

Having the nature of a paraffin. Paraffins are saturated hydrocarbons having no double bonds. They may be straight chain or branched chain. Paraffins are relatively inert but can be oxidized or burned when temperatures are high enough.

Pentane Insolubles

Asphaltic bodies in new or used motor oils insoluble in pentane. Expressed in weight percent. Refer to ASTM Test No. D893.

Pour Point

Lowest temperature at which useful flow properties of a lube oil exist. Refer to ASTM Test No. D97.

PPM

Parts per million by weight.

Precursor

Materials leading to the formation of other compounds.

Raffinate

The purified stream from a liquid-liquid solvent extraction system. The raffinate is nearly solvent free. The second liquid phase is termed the extract and possesses most of the solvent.

Rankine Cycle Engine

A heat engine operating with a recirculating thermodynamic fluid. The steam engine is a Rankine engine.

SAE

Abbreviation for Society of Automotive Engineers.

Saponification Number

A measure of the amount of acidic and saponifiable materials in oils. Expressed as milligram KOH per gram sample. Refer to ASTM Test No. D-94.

GLOSSARY (continued)

Scuffing

Adhesive wear caused by localized welding and followed by surface fractures.

SD, SE

API motor oil service designation. See Table 14 for description.

S.G.

Specific gravity.

Slop Oils, or Slops

Waste oils frequently heavily contaminated with water, fuels, dirt and debris.

Sludge Flocculant

A compound which causes aggregation of small suspended particles and thereby hastens settling.

Sludge Rating

The tendency of an oil to deposit insoluble materials in critical engine parts. A value of 10 indicates a clean engine. Refer to ASTM STP 315E sequence V-C tests.

Solvent Bright Stock

See Bright Stock.

Solvent Neutral Oil

Base stocks of essentially paraffinic nature and having viscosities generally less than ∿600 SSU.

Space Velocity

A measure of the interaction of a catalyst bed with the incoming reactants. Usually expressed as a reciprocal time (e.g., $hr^{-1}$, $sec^{-1}$, etc.). May be expressed as cubic feet reactants per unit time per cubic feet of catalyst.

GLOSSARY (continued)

Spindle Oil

A naphthenic base stock.

SSU

A viscosity unit - Saybolt Seconds Universal.

Steam Stripping

Use of steam to entrain lower boiling compounds from a mixture. The vapor mixture may be condensed and the condensate separated into an aqueous phase and an oil phase.

Sweetening

Removal of sulfur from hydrocarbon stocks.

Tank Bottoms

Heavy sludges accumulating in the bottoms of storage tanks after repeated use.

"Todd" Burner

A commercial burner design of great popularity and featuring peripheral admission of air through a set of louvers mounted perpendicularly to the fuel path.

Varnish Rating

Varnish is an oil-insoluble lustrous deposit not removable by wiping with a soft cloth. Oils are rated (10=clean) by ASTM STP 315E for such deposits on critical engine parts.

Virgin Oil

Oil products manufactured from previously unused petroleum materials.

Viscosity Index

An empirical measure of the effect of temperature on the viscosity of oils. A low index indicates a large change with temperature. Often called the "Dean and Davis" Index. Refer to ASTM D567.

GLOSSARY (continued)

### Viscosity Index Improver

An additive which generally increases the oil viscosity at high temperature, but less so at lower temperatures.

### Wankel Engine

An internal combustion engine.

### White Oil

High purity clear mineral oils of different viscosities and densities. Some used as industrial lubricants and some in pharmaceutical applications.

# SECTION XXII

## APPENDIX I - OIL SPECIFICATIONS AND PERFORMANCE TEST DATA

Table I - 1 API Service Specifications
I - 2 API Automotive Transmission and Axle Lube Designations
I - 3 MIL Spec., MIL-L-46152
I - 4 MIL Spec., MIL-L-2104C
I - 5 ASTM-STP-315 Test Procedure
I - 6 Test Sequence IIA and IIIA (ASTM)
I - 7 Series 3 Oil Performance in DS Test
I - 8 Detroit Diesel Test Cycle
I - 9 Hydraulic Oil Specification
I - 10 Rubber Extender Oil Specification
I - 11 Aviation Oil Specification
I - 12 Heavy Duty Gear Oil Specification
I - 13 Transformer Oil Specification
I - 14 Heavy Oil Cracking Feed Stocks
I - 15 Maryland Lube Oil and Grease Sales
I - 16 U.S. Lube Oil and Grease Sales

## Appendix

## TABLE I-1

## API SERVICE APPLICATIONS
(Ref. 31)

| New API Engine Service Classifications | Previous API Engine Service Classifications | Related Designations Military & Industry |
|---|---|---|
| Service Station Engine Services | | |
| SA | ML | Straight mineral oil |
| SB | MM | Inhibited oil |
| SC | MS (1964) | 1964 MS Warranty Approved,M2C101-A |
| SD | MS (1968) | 1968 MS Warranty Approved, M2C101-B, 6041-M (Prior to July, 1970) |
| SE | None | 1972 Warranty Approved, M2C101-C, 6136-M (Previously 6041-M Rev.), MIL-L-46152[1] |
| Commercial and Fleet Engine Services | | |
| CA | DG | MIL-L-2104A |
| CB | DM | Supp. 1 |
| CC | DM | MIL-L-2104B, MIL-L-46152[1] |
| CD | DS | MIL-L-45199B, Series 3, MIL-L-2104C[2] |

[1] Oils meeting performance requirements of MIL-L-46152 meet the performance requirements of both API Service SE and CC.

[2] Oils meeting performance requirements of MIL-L-2104C meet the performance requirements of both API Service CD and SC.

Appendix

## TABLE I-2

## API AUTOMOTIVE TRANSMISSION AND AXLE LUBE DESIGNATIONS
(Ref. 32)

API-GL-1 - Some manual transmissions spiral-bevel and worm gear under mild conditions. No frictional modifiers and extreme pressure agents utilized.

API-GL-2 - Worm gear axles, with more stringent conditions than above.

API-GL-3 - Spiral bevel and manual transmission under moderately severe speed and load conditions.

API-GL-4 - Characteristic of particularly hypoid in passenger cars operated under high speed, low speed, high torque conditions.

API-GL-5 - Same as above only high speed shock load, low torque and low speed high torque conditions.

API-GL-6 - High offset hypoid gears (i.e., above 2" offset and approaching 25% ring-gear diameter). Operated under high speed, high performance conditions.

Appendix

## TABLE I-3

## MIL-L-46152; MILITARY ENGINE OIL SPECIFICATIONS FOR COMMERCIAL AND ADMINISTRATIVE APPLICATION

(Ref. 120)

| Property | Grade 10 | Grade 30 | Grade 10W-30 | Grade 20W-40 |
|---|---|---|---|---|
| Viscosity range @ 210F (centistokes) | 5.7-<br>7.5 | 9.6-<br>12.9 | 9.6-<br>12.9 | 12.9-<br>16.8 |
| Viscosity range at 0°F[1] (centipoises) | | | | |
| Min. | 1200- | -- | 1200- | 2400 |
| Max. | 2400 | -- | 2400 | 9600 |
| Viscosity index (min.) | -- | 75 | -- | -- |
| Pour point, °F (max.) | -25 | 0 | -25 | -10 |
| Stable pour point, °F (max.)[2] | -25 | -- | -25 | -10 |
| Flash point, °F (min.) | 400 | 425 | 400 | 415 |
| Specific Gravity (API)[3] | X | X | X | X |
| Carbon residue[3] | X | X | X | X |
| Phosphorus[3] | X | X | X | X |
| Chlorine[3] | X | X | X | X |
| Sulfur[3] | X | X | X | X |
| Sulfated residue[3] | X | X | X | X |
| Organo-metallic components[3] | X | X | X | X |

---

[1] Report measured, apparent viscosity at 0°F in centipoises for grades 10, 102-30, and 20W-40 oils.

[2] After being cooled below its pour point, the oil shall regain its homogeneity on standing at a temperature not more than 10°F above the pour point.

[3] Values shall be reported ("X" indicates report).

## TABLE I-4

## MIL-L-2104C; MILITARY ENGINE OIL SPECIFICATIONS FOR TACTICAL APPLICATION

(Ref. 121)

| Property | Grade 10 | Grade 30 | Grade 40 | Grade 50 |
|---|---|---|---|---|
| Viscosity range @ 210F (centistokes) | 5.7-<br>7.5 | 9.6-<br>12.9 | 12.9-<br>16.8 | 16.8-<br>22.7 |
| Viscosity range @ 0°F (centipoises) | 1200-<br>2400 | --<br>-- | --<br>-- | --<br>-- |
| Viscosity index (min.) | -- | 75 | 80 | 85 |
| Pour point, °F. (max.) | -25 | 0 | 5 | 15 |
| Stable pour point, °F (max.)[2] | -25 | -- | -- | -- |
| Flash point, °F. (min.) | 400 | 425 | 435 | 450 |
| Specific gravity, (API)[3] | X | X | X | X |
| Carbon residue [3] | X | X | X | X |
| Phosphorus [3] | X | X | X | X |
| Chlorine [3] | X | X | X | X |
| Sulfur [3] | X | X | X | X |
| Sulfated residue [3] | X | X | X | X |
| Organo-metallic components[3] | X | X | X | X |

---

[1] Report measured, apparent viscosity at 0°F in centipoises for grade 10 oil.

[2] After being cooled below its pour point, the oil shall regain its homogeneity on standing at a temperature not more than 10°F above the pour point.

[3] Values shall be reported ("X" indicates report).

Appendix

## TABLE I-5

## TEST CONDITIONS OF A 4-HOURS CYCLE OF SEQUENCE V ON THE 1957 LINCOLN V-8 ENGINE OF 368 CU. IN. FOLLOWING ASTM-STP 315
(48 CYCLES IN A TEST)
(Ref. 34)

| Test Conditions | Cycle of 4 hrs.<br>Stage I (idle) | Stage II (cold) | Stage III (hot) |
|---|---|---|---|
| Time, minutes | 45 | 120 | 75 |
| Speed, r.p.m. | 500 ± 25 | 2500 ± 25 | 2500 ± 25 |
| Load, b.h.p. * | none | 105 ± 2 | 105 ± 2 |
| Crankcase oil temp. (°F) | 120 ± 5 | 175 ± 5 | 205 ± 5 |
| Water out temp. (°F) | 115 ± 5 | 125 ± 5 | 170 ± 5 |
| Water in temp. (°F) | 110 ± 5 | 115 ± 5 | 160 ± 5 |
| Difference in water temp. (°F) | 10 to 15 | 10 to 15 | 10 to 15 |
| Oil pan water spray (°F) | 80 ± 5 | 80 ± 5 | 80 ± 5 |
| Intake manifold mixture temp.(°F) | 51.7 (125) | 51.7 (125) | 51.7 (125) |
| Air/fuel ratio | 9.5 ± 0.5:1 | 15.5 ± 0.5:1 | 15.5 ± 0.5:1 |
| Ignition timing, deg. B.T.D.C. ** | 6 to 8 | 27 to 20 | 27 to 20 |
| Blow-by rate (cu.ft./hr.) | not specified | not specified | 150 ± 30 |
| Exhaust back pressure in. Hg. | 0.0 to 0.2 | 2.0 ± 0.5 | 2.0 ± 0.5 |
| Oil pressure (p.s.i.) | 15 min. | 35 to 50 | 35 to 50 |
| Air flow (lb./hr.) | 45 to 65 | 690 to 750 | 690 to 750 |
| Fuel flow (lb/hr.) | 5.0 to 6.5 | 45 to 50 | 45 to 50 |

* b.h.p. - brake horsepower

** B.T.D.C. - before top dead center

## TABLE I-6

## TEST SEQUENCE IIA AND IIIA (ASTM)
(Ref. 34)

| | |
|---|---|
| Engine - Oldsmobile | 1964 V-8, 6.4 litres (394 cu.in.) |
| Fuel: TEL*/Sulfur | 1.05% /0.06% |
| Engine break-in | No |
| Test duration | 62 hr. (no down time) |
| Crankcase oil filler tube | Plugged for IIA and IIIA |
| Oil filter | Yes |
| Jacketed top and rocker covers | Yes |
| Jacket coolant | 40% glycol-60% water plus inhibitors |
| Engine water jacket cleaning | Chemically cleaned |
| Parts rated for rust: | |
| Valve lifter body | Yes |
| Valve lifter plunger | Yes |
| Valve lifter ball | Yes |
| Relief valve | Yes |
| Push rod | Yes |

* TEL - tetraethyl lead

## TABLE I-7

## SERIES 3 OIL PERFORMANCE IN DS* TEST (57)
(Ref. 35)

| | |
|---|---|
| Cylinder liner scuffing, % | 13 |
| Cylinder liner wear, in. avg.** | 0.0005 |
| Piston ring groove filling, % | |
| Fire ring groove | 1 % filled |
| Top compression groove | 31 " " |
| Second compression groove | 9 " " |
| Third compression groove | 2 " " |
| First oil ring groove | 0 " " |
| Second oil ring groove | 0 " " |
| Fire ring sticking | 0 (No) |
| Other ring sticking | 0 (No) |
| Intake port plugging, % | 2 |

* Diesel Service

** inches - average

## TABLE I-8

## DETROIT DIESEL 6V-71 "DS"* TEST CYCLE

(Ref. 35)

| | Time min. | Speed r.p.m. | Load** b.h.p. | Water Out*** °F | Oil Sump °F |
|---|---|---|---|---|---|
| Oil charge: 26 quarts | | | | | |
| 1. Break-in .. .. .. | 60 | 1000 | 30 | 160 | 160 |
| | 60 | 1800 | 160 | 160 | 200 |
| | 60 | 2300 | 200 | 160 | 220 |
| 2. Oil adjustment .. .. | Drain two-quart levelling sample. Add two-quarts fresh oil. Bring level to "full" mark on dipstick using levelling sample. | | | | |
| 3. Valve adjustment .. .. | Adjust (exhaust) valve clearance | | | | |
| 4. Inspection .. .. .. | Compression rings, liners, ports | | | | |
| 5. Truck cycle: | | | | | |
| Sequence 1 (repeat 9 times) | 30 | 500 | 2 | 120 | 120 |
| | 90 | 2300 | 225 | 195 | 255 |
| Sequence 2 .. .. .. | 60 | 0 | 0 | (Shutdown) | |
| | Check, but do not adjust exhaust valve clearance.<br>Inspect cylinder liners and compression rings | | | | |
| Sequence 3 .. .. .. | 240 | 2400 | 230 | 195 | 255 |
| | At end, withdraw two-quart levelling sample.<br>Add four quarts fresh oil | | | | |
| Sequence 4 .. .. .. | 60 | 0 | 0 | (Shutdown) | |
| | Bring oil level to "full" mark on dipstick using levelling sample | | | | |

Repeat truck cycle 12 times. Take 12 oz. used oil sample after 1, 4, 7, 10 and 12 cycles. Replace with fresh oil.

* Diesel service

** brake horsepower

*** outlet temperature

Appendix

## TABLE I-9

## HYDRAULIC OIL SPECIFICATION

(Ref. 18)

| Characteristic | Value |
|---|---|
| Gravity (°API) | 30 |
| Viscosity @ 100°F (SSU) | 160 |
| Viscosity Index | 101 |
| ASTM Viscosity | 150 |
| Pour Point (°F) | -24 |
| Neutralization Number | 0.70 |

Appendix

## TABLE I-10

## RUBBER EXTENDER OIL SPECIFICATION

(Ref. 41)

| Characteristic | Value |
|---|---|
| ASTM Number | 104B |
| Viscosity @ 100° F (SSU) | 150 |
| Viscosity @ 210° F (SSU) | 44 |
| Density (gm/cc) | 0.865 |
| ASTM Color | 1 |
| Neutralization Number | 0.01 |
| Pour Point (°F) | +15 |
| Flash Point (°F) | 420 |

Appendix

## TABLE I-11

## AVIATION OIL SPECIFICATION

(Ref. 42)

| Characteristic | Value |
|---|---|
| SAE Number | 40 |
| Gravity | 29.5 |
| Viscosity @ 100° F (SSU) | 630 |
| Viscosity @ 210° F (SSU) | 80 |
| Viscosity Index | 119 |
| Pour Point (°F) | -15 |
| Flash Point (°F) | 520 |

## TABLE I-12

## HEAVY DUTY GEAR OIL SPECIFICATION
(Ref. 18)

| Characteristic | ASTM GRADE 215 | ASTM GRADE 700 |
|---|---|---|
| AGMA* Number | 1 | 4 |
| Viscosity @ 100°F (SSU) | 215 | 720 |
| Viscosity @ 210°F (SSU) | 48 | 76 |
| Viscosity Index | 101 | 100 |
| Gravity (°API) | 30.5 | 28.5 |
| Flash Point (°F) | 420 | 510 |
| Pour Point (°F) | -10 | -1 |
| Neutralization Number | 0.06 | .08 |

* American Gear Manufacturers Assoc.

## TABLE I-13

## TRANSFORMER OIL SPECIFICATION

(Ref. 18)

| Characteristic | Value |
|---|---|
| Density | 0.89 |
| Fire Point (°F), COC * | 335 |
| Flash Point (°F), COC * | 310 |
| Pour Point (°F) | -75 |
| Viscosity @ 100 °F (SSU) | 60 |
| Interfacial tension (oil/distilled water) @ 25°C (dynes/cm) | 49 |
| Neutralization Number | 0.0 |
| Water (ppm) | 25 |
| Dielectric Strength (kilovolts) | >35 |
| Power factor, % @ 25 °C | 0.1 |

* Cleveland Open Cup

## TABLE I-14

## HEAVY OIL CRACKING FEED STOCKS

(Ref. 43)

| Characteristics | Value |
|---|---|
| Initial Boiling Point (°F) | 352 |
| 50% Boiling Point (°F) | 565 |
| End Boiling Point (°F) | 687 |
| Weight % Paraffin | 37.7 |
| Weight % Cyclic Paraffin | 36.9 |
| Weight % Alkyl Benzenes | 8.4 |
| Weight % Indanes, Tetralins | 4.1 |
| Weight % Indenes | 2.7 |
| API Gravity Range (°API) | (28 to 40) |

## Appendix I

## TABLE I-15

## STATE OF MARYLAND

## HISTORICAL LUBE OIL AND GREASE SALES

| TYPE | 1947 | 1951 | 1956 | 1958 | 1960 | 1962 | 1965 |
|---|---|---|---|---|---|---|---|
| Automotive oil (gallons) | 14,532,000 | 12,600,000 | 11,004,000 | 12,600,000 | 11,996,000 | 12,458,000 | 12,901,000 |
| Aviation oils (gallons) | 130,000 | 210,000 | 129,000 | 106,000 | 97,000 | 90,000 | 52,000 |
| Industrial Lube Oils (gallons) | 7,560,000 | 4,746,000 | 3,582,000 | 5,838,000 | 7,465,000 | 9,980,000 | 9,885,000 |
| Other Industrial Oils (gallons) | 1,344,000 | 2,142,000 | 4,368,000 | 2,557,000 | 1,941,000 | 3,752,000 | 3,101,000 |
| Automotive & Aviation Greases (equivalent gallons based on 9 lbs/gallon) | 756,000 | 1,365,000 | 805,000 | 875,000 | 715,000 | 792,000 | 706,000 |
| Industrial Greases (equivalent gallons based on 9 lbs/gallon) | 738,500 | 462,000 | 469,000 | 595,000 | 640,900 | 642,000 | 881,000 |
| Total Volume (gallons) | 25,061,000 | 21,525,000 | 20,357,000 | 22,571,000 | 22,855,000 | 27,774,000 | 27,526,000 |

---

* Note: Volume based on 9 lb/gallon density (References: 1 & 3)

## Appendix I

## Table I-16

## HISTORICAL NATIONAL OIL AND GREASE SALES

| Type | 1947 | 1951 | 1956 | 1958 | 1960 | 1962 | 1965 |
|---|---|---|---|---|---|---|---|
| Automotive Oils (1000 gallons) | 732 | 827 | 930 | 842 | 924 | 945 | 1002 |
| Aviation Oils (1000 gallons) | 10.9 | 29.7 | 22.1 | 27.3 | 20.6 | 22.2 | 19.6 |
| Industrial Lube Oils (1000 gallons) | 454 | 439 | 494 | 428 | 478 | 511 | 630 |
| Other Industrial Oils (1000 gallons) | 200 | 241 | 201 | 213 | 227 | 287 | 330 |
| Auto & Aviation Grease (1000 gallons) | 54.7 | 56.5 | 62.0 | 58.6 | 72.9 | 62.5 | 58.6 |
| Industrial Grease (1000 gallons) | 27.2 | 36.7 | 36.3 | 30.5 | 41.2 | 47.4 | 56.7 |
| TOTAL | 1477 | 1629 | 1744 | 1641 | 1762 | 1874 | 2095 |

---

* Note: Volume based on 9 lb/gal density (References: 1 & 3)

# APPENDIX II - LEGAL MATERIALS

A. Laws of Various Jurisdictions which Apply to Waste Oil Disposal

B. Regulation 4.02 - Prevention of Oil Pollution

C. Massachusetts Laws and Regulations Concerning Waste Oil Disposal

D. Federal Republic of Germany - 1968 Waste Oil Law

E. H.R. 15502 - Proposed "National Oil Recycling Act"

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## APPENDIX II-A

### LAWS OF VARIOUS JURISDICTIONS WHICH APPLY TO WASTE OIL DISPOSAL

| Jurisdiction* | On-Site Fire Hazard Control Ordinance | Sewage Line Explosion Control Ordinance | Pollution of Drinking Water Supply Ordinance | Water Pollution Ordinance |
|---|---|---|---|---|
| City of Annapolis | | City of Annapolis Code §21-18 | Yes | |
| Anne Arundel Co. | | | Yes | |
| Baltimore Co. | | | Yes | |
| City of Baltimore | | | Yes | |
| Garret Co. | | | Yes | Garrett County Code §36-1 |
| Town of Hagerstown | Hagerstown Code §38-146 | Hagerstown Code §38-150 | Yes | |
| Howard Co. | | | Yes | Howard County Code §289<br>Howard Co. Zoning Regs. 16.08 |
| Montgomery Co. | Montgomery Co. Code §86-36(K) | | Yes | |
| Prince George's Co. | | | Yes | |
| Town of Riverdale | Ordinance 57-7 | Ordinance 57-7 | Yes | |

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* These jurisdictions represent 80% of Maryland's population.

# Appendix II-B

Maryland State Department of
Natural Resources

08.05.04.02

Rules and Regulations

Promulgated by
Water Resources Administration
Natural Resources Building, Annapolis, Md. 21401

# WATER RESOURCES REGULATION

## 4.02

## PREVENTION OF OIL POLLUTION

Including Requirements For:

- Operations Involving the Transfer, Storage, Separating, Removing, Treating and Dispersing of Oil
- Oil Handler's Permit
- Oil Vehicle Operator's Certificate

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Pursuant to the provisions of Section 26A of Article 96A of the Annotated Code of Maryland, (1957 Edition, as amended), the following regulation including requirements and procedures is established by the Water Resources Administration, an agency of the Department of Natural Resources, effective October 20, 1972.

SECTION I. Definitions

A. For the purpose of this regulation, the terms "pollution", "wastes", "treatment works", "disposal system", "waters of the State", and "person" shall be defined as set forth in Section 24 of Article 96A of the Code.

B. The following words and phrases as used in this regulation have the following meaning unless a different meaning is plainly required by context:

(1) Administration - shall mean the Maryland Water Resources Administration, a member agency of the Department of Natural Resources of the State of Maryland.

(2) Collecting Agents - shall mean chemicals or other agents that can gell, congeal, herd, entrap, fix or make the oil mass more rigid or viscous to facilitate its removal from the water surface.

(3) Department - shall mean the Maryland Department of Natural Resources.

(4) Discharge - shall mean any spilling, leaking, pumping, pouring, emitting, emptying, or dumping into the waters of the State, either directly or indirectly.

(5) Dispersants - shall mean those chemical agents or compounds which emulsify, disperse or solubilize oil or act to further the surface spreading of oil slicks in order to facilitate dispersal of oil.

(6) Offshore Facility - shall mean any installation of any kind located in, on, or under, any of the navigable waters within the State of Maryland other than a vessel.

(7) Oil - shall mean any of a number of unctuous combustible substances that are liquid at ambient temperature and atmospheric pressure, or easily liquefiable on warming and soluble in ether. It shall include but not be limited to, petroleum, fuel oil, gasoline, kerosene, lubricating oil, oil bearing sludge, oil refuse, oil mixed with ballast or bilge, and oil mixed with wastes.

(8) Onshore Facility - shall mean any installation (including, but not limited to terminals, motor vehicle and rolling stock) of any kind located in, on, or under any land within the State of Maryland.

(9) Operator - shall mean that person or those persons with responsibility for the management and performance of each facility.

(10) Permit - shall mean an OIL HANDLER'S PERMIT.

(11) Person in Charge - shall mean a person designated by the permit holder as the one in charge of the transfer of oil to or from any facility.

(12) Sinking Agents - shall mean those chemicals or other agents that can physically sink oil below the water surface.

(13) Slop - shall mean a mixture of oil, water and sediment.

(14) Sorbent - shall mean any substance that takes up and holds oil by either adsorption or absorption.

(15) Spill - shall mean any loss of control or release of oil such that it moves or is capable of moving into the aquatic environme

(16) Transport - shall mean a tractor-trailer vehicular unit, usually of 5,000 gallons capacity or greater.

(17) Truck Tank - shall mean a self-contained vehicular unit (meaning the automotive power and the hauling capacity are contained in one complete package). A truck tank may be of any capacity up to the road limitation on axle weights, approximately 3,200 gallons on two axles.

(18) Vessel - shall mean every watercraft or other artificial contrivance used or capable of being used, as a means of transportation on waters of the State.

## SECTION II. General

### A. OPERATIONS REQUIRING PERMIT:

(1) This section applies to any commercial or industrial operation involving the handling of oil regardless of the nature, size or location of the operation.

(2) No person shall engage in any commercial or industrial operation involving the transfer, storage, separating, removing, treating and dispersing of oil unless approval is received from the Administration in the form of a PERMIT indicating that the activities at that facility or part thereof, are in conformity with this regulation.

B. GENERAL CONDITIONS FOR ISSUANCE OF PERMIT:

Upon application for a PERMIT by the owner or authorized operator of any facility, the Administration will issue the PERMIT therefor, after review of the oil handling procedures and practices involved, and inspection of the facility, if necessary, when the Administration determines that the requirements of this regulation can be met, that the owner or authorized operator of the facility is properly and adequately equipped to prevent oil pollution and to control oil spills, and has the capability to handle oil in accordance with this regulation and without discharge into the waters of the State.

C. REQUIREMENTS FOR APPLICATION:

(1) An application for a PERMIT shall be submitted in writing, by the owner or the authorized operator of the facility, accompanied by a copy of the facility's containment and clean-up plan, or a copy of the facility's operations manual in the case of marine oil transfer facilities. (Special requirements and exemptions for marine oil transfer facilities are described in Section III, and those for garages, etc. are described in Section VIII).

(2) The plan for containment and clean-up shall include the following information:

  (a) List of persons to be notified in the event of a spill at the facility.

  (b) Provisions for quick control of an oil spill, including personnel and equipment available for the containment and removal of such spill.

  (c) Communications facilities available for use in control and clean-up operations.

  (d) List of qualified contractors, equipment and facilities available for oil spill clean-up operations.

  (e) Additional information the Water Resources Administration deems necessary.

(3) An application for a PERMIT shall be submitted on an approved form, at least 60 days prior to the date of intended operation.

(4) A PERMIT issued by the Administration shall be effective for a period of 5 years unless it is surrendered, suspended, revoked, otherwise terminated, or issued by the Administration, for reasons stated, for a shorter period of time.

D. AMENDMENT, SUSPENSION OR REVOCATION OF PERMIT:

(1) The Administration may suspend or revoke a PERMIT, or require

amendments thereto at any time the facility fails to meet any of the requirements of this regulation, including the rendering of false information within the application. The notification of suspension, revocation or requirements for amendments shall be in writing, shall state the effective date of such action, and shall be in accordance with the provisions of this regulation and the rules of procedure of the Administration.

(2) (a) In the event the Administration determines that it is necessary to amend, suspend, or revoke a PERMIT, the Administration shall so notify the permit holder, in writing, of a date not less than 14 days from the date of the notice, on or before which the permit holder may submit written information and arguments regarding the proposed amendments, suspension, or revocation.

(b) After considering all relevant material presented, the Administration shall notify the permit holder of its decision to suspend or revoke the PERMIT, or of any amendments required, or the Administration shall rescind its proposed action to suspend, revoke or require amendments to the PERMIT.

(c) Any suspension, revocation or requirement for amendment to a PERMIT shall become effective not less than 30 days after the date of the notice, unless the permit holder petitions the Department to reconsider its action, in which case the effective date shall be delayed pending a final decision by the Administration.

(d) Any appeal from a final decision of the Administration shall be in accordance with the rules of procedure of the Administration.

(3) In the event the Administration decides that a PERMIT must be amended, or the permit holder seeks amendments to the PERMIT, the permit holder shall submit an application for an amended PERMIT at least 30 days prior to the proposed effective date of such amendment unless a shorter period of time is authorized by the Administration.

(4) The Administration may, on its own initiative, amend a PERMIT if after inspection it finds that the PERMIT, or the plan for containment and clean-up (operations manual for marine oil transfer facilities) on which the PERMIT is based, is not adequate to meet the requirements of this regulation.

(5) In the event the Administration finds that there exists at any facility a special condition requiring immediate action to prevent the discharge of oil to the waters of the State, and the use of the procedures described herein for the amendment, suspension or revocation of a PERMIT would cause undue delay and would be

impracticable or contrary to the public interest, the Administration may issue an amendment, suspension, or revocation effective immediately. In such case, the Administration shall state in a notice to the permit holder the reasons for its findings and action, and the permit holder may within 30 days of receipt of said notice, petition the Administration, in writing, to reconsider the amendment, suspension, or revocation.

## E. PROHIBITION AGAINST OIL POLLUTION:

(1) No person shall pump, discharge, throw, drain or deposit, or cause to be deposited, into the waters of the State, oil or other matter containing oil which will cause pollution of such waters, or will cause a violation of the water quality standards of the State of Maryland.

(2) No person shall pump, discharge, or deposit, or cause to be deposited, bilge or ballast water, or water from any receptacle containing oil, in such a manner whereby oil may escape into the waters of the State, causing pollution of such waters, or causing a violation of the water quality standards of the State of Maryland.

(3) Persons violating these prohibitions are subject to the sanctions of Article 96A, Section 28A, in addition to the revocation, or suspension provisions within paragraph D above.

## F. TESTING OF OIL POLLUTION CONTROL MEASURES:

Nothing contained herein shall prohibit the testing and demonstration of equipment and materials for the control of oil pollution.

## G. REPORT OF OIL SPILL OR DISCHARGE:

(1) Any person discharging or permitting the discharge of oil or any person, either actively or passively participating in the discharge or spilling of oil into the waters of the State whether from a land-based installation, including vehicles in transit, or from any vessel, ship or boat of any kind, shall not knowingly fail to report the incident immediately to the appropriate federal authority and to the Administration, and shall not knowingly fail to remain available until clearance to leave is given by the appropriate officials.

(2) The required report of an oil spill or discharge may be made in person, in writing or by telephone to the Water Resources Administrator or his duly authorized representative, and shall include:

(a) Time of discharge;

(b) Location of discharge;

(c) Type and quantity of oil;

(d) Assistance required;

(e) Name, address and telephone number of person making the report; and

(f) All other pertinent and necessary information.

(3) After the removal and clean-up work has been completed, the person responsible for the spill shall prepare a complete written report of the occurrence and promptly submit such report to the Administration. The written report shall include the following information:

(a) Date, time and place of spill;

(b) Amount and type of oil spilled;

(c) Complete description of circumstances contributing to the spill;

(d) Complete description of containment, removal, and clean-up operations including costs of the operations;

(e) Procedures, methods and precautions instituted to prevent a recurrence of an oil spill from the facility involved; and

(f) Such other information as considered necessary or required by the Administration for a complete description of the spill incident.

(4) Notification received pursuant to this regulation or information obtained by the exploitation of such notification shall not be used against any such person in any criminal case, except a prosecution for perjury or for giving a false statement.

## H. REMOVAL AND RESPONSIBILITY:

(1) Responsibility for the prompt control, containment and removal of any spilled oil shall be with the person, or persons, responsible for the illegal discharge, and shall remain with such person or persons until removal of spilled oil has been accomplished to the satisfaction of the Administration.

(2) Removal of oil from the waters of the State shall be accomplished by physical or mechanical means such as the use of skimming devices or vacuum systems or by the use of inert sorbent material.

(3) If sorbent material is employed, such material shall be removed from the waters of the State and disposed of as directed by the Administration.

(4) Collecting agents, dispersants or sinking agents shall not be used on or in the waters of the State except when authorized by the Administration.

(5) In case of emergency, nothing in this regulation shall be construed to prevent the person in charge of the oil handling operation from pursuing the most effective action which in his judgment will best control or rectify the conditions constituting the emergency or the hazard involved.

## SECTION III. Marine Oil Transfer Facilities

### A. OPERATIONS REQUIRING PERMIT:

A PERMIT is required for the operation of each onshore or offshore facility which transfers oil to or from any vessel having a capacity of 10,000 U. S. gallons or more.

### B. REQUIREMENTS FOR APPLICATION FOR PERMIT:

(1) An applicant for a PERMIT for a marine oil transfer facility shall submit an application in writing accompanied by a copy of an operations manual which describes:

(a) The means and procedures that the applicant uses or will use to meet the operating rules and equipment requirements prescribed by this regulation; and

(b) The duties and responsibilities of operations personnel in conducting oil transfer operations.

(2) In determining whether or not the manual meets the requirements of this regulation, the Administration shall consider the size, complexity, and the storage and transfer capacity of the facility.

(3) The operations manual shall contain:

(a) The geographic location of the facility;

(b) A physical description of the facility including a plan of the facility showing mooring areas, transfer locations, control stations, and locations of oil spill clean-up equipment;

(c) The hours of operation of the facility;

(d) The sizes, types, and number of vessels to or from which the facility can simultaneously transfer oil;

(e) The grade and trade name of each product not compatible with oil which is transferred at the facility;

(f) The minimum number of personnel on duty during transfer operations;

(g) The names and telephone numbers of facility, Coast Guard, other Federal, Water Resources Administration, and other personnel who will be called or contacted by the employees of the facility in the event of an oil spill or other emergency;

(h) A description of the communications system and the emergency warning system available;

(i) A description and instructions for use of drip and discharge collection, and vessel slop reception facilities;

(j) A description of and the location of each emergency shutdown system;

(k) Location and instructions for use of the containment equipment; and

(l) Procedures for:

    (1) Operating each loading arm including the limitations of each loading arm;

    (2) Transferring oil;

    (3) Completion of pumping;

    (4) Emergencies;

    (5) Reporting oil discharges; and

    (6) Containing discharges.

C. REQUIREMENTS FOR OIL TRANSFER:

No person shall commence or cause to be commenced or consent to the commencement of marine bulk oil transfer operations, including bunkering, unless the following provisions are complied with:

(1) A licensed officer or a certified tankerman, certified under U. S. Coast Guard regulations, or for foreign vessels, their equivalent, who has full knowledge of the vessel's tank and cargo handling system shall be present and in charge of cargo handling for the vessel (PIC/CHV) during the entire oil transfer operations.

(2) At each marine oil terminal the transfer operation shall be under the direct supervision of an individual designated and authorized by the permit holder of the marine transfer facility as the person in charge of the oil transfer operation (PIC/OTO).

(3) Complete check of weather forecast shall be made in order to ascertain that the transfer operation may be commenced and pursued under weather conditions favoring safe oil transfer.

(4) Prior to the start of oil transfer operations, the maximum operating pressures, the approximate handling rate and sequence at which oil will be transferred, shall be made known and agreed upon by the person in charge on the vessel (PIC/CHV) and by the person in charge on the pier (PIC/OTO).

(5) Prior to the start of oil transfer operations, the emergency procedures to be followed in order to stop and contain any discharge of oil into the waters of the State shall be made known and agreed upon by the person in charge on the vessel (PIC/CHV) and by the person in charge of the oil transfer operations (PIC/OTO).

(6) Each facility shall have a means that enables two-way voice communication between the person in charge on the vessel (PIC/CHV) and the person in charge of the oil transfer operations at the facility (PIC/OTO). Visual or audible emergency warning devices may be employed to supplement the voice communication system.

(7) Each person in charge of oil transfer operations (PIC/OTO) shall carry evidence of his designation as the person in charge when he is engaged in transfer operations unless such evidence is readily available at the facility.

## D. QUALIFICATIONS OF PERSON IN CHARGE OF OIL TRANSFER OPERATIONS:

The permit holder may not utilize the services of any person, to be in charge of oil transfer operations (PIC/OTO) unless:

(1) The PIC/OTO has had at least 48 hours of experience in oil transfer operations under the supervision of the permit holder or under a person qualified to direct and supervise oil transfer operations, except that for new facilities the Administration may authorize alternative experience requirements.

(2) The permit holder has determined that the PIC/OTO has the capability to operate the oil transfer equipment of the facility and is familiar with the requirements of State and Federal regulations pertaining to oil transfers, oil spill prevention, and oil pollution control.

## E. REQUIREMENTS DURING OIL TRANSFER:

(1) During marine oil transfer operations a minimum of two individuals, one aboard the vessel (PIC/CHV) and one on shore (PIC/OTO), but more than two if deemed necessary by the permit holder or by the Administration, shall be on duty providing constant supervision over the safe transfer of the oil. Such persons shall be trained

in the procedures employed in the safe handling of oil, the prevention of oil spills and the containment and removal of oil spilled into the waters of the State.

(2) Each oil transfer facility shall have ready access to oil containment equipment sufficient to contain oil discharged into the water, in light of:

(a) Oil handling rates;

(b) Oil capacity susceptible to being spilled;

(c) Frequency of facility operations;

(d) Tidal and current conditions;

(e) Facility age, capacity, arrangement, and past experience; and

(f) If the equipment is shared, the expected frequency of use and probability of immediate availability.

Such access may be by direct ownership, joint ownership, cooperative venture, or contractual arrangement.

(3) A vessel's moorings shall be adequate to hold in all expected conditions of surge, current, and weather and sufficiently long to allow adjustment for changes in draft and tide during the transfer operation.

(4) All scuppers and holes shall be plugged during transfer operations. If the scuppers must be unplugged to drain water from the deck area, they shall be tended constantly and the plugs replaced immediately.

(5) During oil transfer operations, sea valves connected to the cargo and ballast discharge piping shall be tightly closed and sealed.

(6) Adequate valves shall be located in dock lines to prevent backflow in case of hose or manifold failure.

(7) Pumps and pipeline connections shall have catch trays positioned under potential leak areas. Such trays shall be emptied into a receptacle of sufficient capacity, following each material transfer.

F. LIGHTING REQUIREMENTS:

For transfer operations conducted between sunset and sunrise, lighting shall be provided to illuminate:

(1) Each transfer connection point on the facility with a minimum lighting intensity of 10 foot-candles;

(2) Each work area on the facility with a minimum lighting intensity of 2 foot-candles;

(3) Each transfer connection point on any barge moored at the facility, to or from which oil is transferred, with a minimum lighting intensity of 10 foot-candles; and

(4) Each work area on any barge moored at the facility, to or from which oil is transferred, with a minimum lighting intensity of 2 foot-candles.

(5) The lighting intensity shall be measured on a horizontal plane 3 feet above the barge deck or walking surface.

## G. CONDITIONS REQUIRING DELAY OR DISCONTINUANCE OF OIL TRANSFER OPERATIONS:

Transfer operations shall not be commenced, or if commenced shall be discontinued, under the following conditions:

(1) If any transfer component is releasing oil into the water;

(2) If weather forecasts predict for the region of the facility that winds will reach gale force, or that heavy rain, sleet, snow or other storm conditions will reduce visibility or otherwise increase the risk of oil spills, or if such severe weather conditions occur after transfer operations have been commenced;

(3) If fire occurs in the oil transfer facility or in its immediate vicinity;

(4) At any time the transfer system is functioning contrary to the standard operating procedures of the facility;

(5) If a break occurs in the transfer system;

(6) If there is any apparent discrepancy in the quantity of oil transferred;

(7) If the communication system is not operative;

(8) If oil from the transfer facility is in the water near any transfer component; or

(9) If the spill prevention and control system is not serviceable.

## H. SECURITY OF PUMP CONTROLS:

Pump controls for dock-mounted pumps shall be secured in the closed position or electrically isolated when not in service.

## I. TESTING AND USE OF MARINE HOSES:

(1) Marine transfer flexible hoselines used in oil transfer operations shall be subjected to hydrostatic testing on at least an annual basis. Each hose shall be marked with an identification number. A log shall be maintained showing the corresponding hose number. The hose or the log shall show test pressure, date and place of test, person performing the test, manufacturer's recommended working pressure and burst pressure.

(2) Hydrostatic testing shall include the following procedures:

(a) Hydrostatic tests and inspection of hoses shall consist of subjecting the hoses to the action of internal water or other appropriate fluid pressure under specified conditions.

(b) Hydrostatic pressure shall be applied by means of a hand or power-driven hydraulic pump or an accumulator system, and it shall be equal to the manufacturer's working pressure.

(c) The hose shall be filled with water or other appropriate fluid prior to application of pressure with a test pump, allowing all air in the hose to escape through a petcock provided for the purpose. The petcock shall then be closed and the pressure shall be applied at a uniform rate of increase, and held for at least fifteen (15) minutes while a visual inspection for hose leaks, defects or weaknesses is made. Pressure shall be measured with a calibrated gage.

(3) Hoses shall not be subjected to transfer pressures greater than the manufacturer's recommended working pressure. Hoses shall be of a grade suitable for oil service and shall have been designed to withstand pressure of the shut-off head of the cargo pump or pump relief valve setting, but in no case less than 150 pounds per square inch.

(4) Marine oil dispensing hoses not requiring mechanical connection to receiving tanks shall be equipped with a self-closing nozzle or with a valve that must be held open by manual control while making a delivery.

(5) All suction, pump or gravity discharge hoses shall be of liquid tight connection.

(6) Hoses and fittings indicating excessive wear or structural failure shall not be utilized.

## SECTION IV. Oil Storage Facilities

### A. OPERATIONS REQUIRING PERMIT:

No oil storage facility may be utilized for any oil storage operation where the storage exceeds 10,000 gallons, regardless of the nature, or location of the operation, without first complying with the permit requirements of Section II of this regulation.

### B. REQUIREMENTS FOR ABOVE-GROUND OIL STORAGE:

(1) Above-ground oil storage and keeping sites, constructed or installed after the effective date of this regulation, shall be surrounded with a continuous dike or wall capable of effectively holding the total volume of the largest storage container located within the area enclosed by the dike, or wall. The construction and composition of such emergency holding area shall be such as to be able to prevent movement of oil from this area into the waters of the State. The nature of the soil and the ground water conditions at the site shall be taken into consideration in the design and/or location of the emergency holding area.

(2) Each fill line which enters a tank below the liquid level shall have adequate valves located as closely as possible to the bulk storage tank.

(3) Seams, rivets, nozzle connections, valves and pipelines directly connected to above-ground oil storage tanks shall be visually examined at least once a month and oil leaks shall be promptly corrected.

### C. DIKE DRAINAGE:

(1) Any oil contaminated surface drainage leaving the containment area and capable of reaching the waters of the State, shall be passed through an oil separating system approved by the Administration, unless other oil pollution control measures acceptable to the Administration are provided.

(2) Flapper-type drain valves shall not be used to drain diked areas. Drain valves for dikes shall be of manual open-and-close design, and shall be kept in the closed position, and shall be locked, when not used to drain trapped water.

### D. REQUIREMENTS FOR BURIED OIL STORAGE:

Buried tanks, regardless of size, installed after the effective date of this regulation, shall be protected from external corrosion by standard techniques, such as coating, wrapping, cathodic protection, etc., to retard corrosive action. The type of protection shall be determined by the nature of the soil and ground water conditions.

### E. AUXILIARY ALARM SYSTEMS:

High liquid level gauges or alarm systems as well as pump cut-off devices shall be installed by the owner or the authorized operator in all oil storage tanks, whenever in the judgment of the Administration there is a possibility that oil may be lost by overflowing. Because such emergency devices can fail to operate, their use for spill prevention purposes shall be considered only as auxiliary and supplementary to the use of personnel engaged in the transfer operation.

## SECTION V. Oil Delivery By Truck Tank or By Transport

### A. OPERATIONS REQUIRING PERMIT:

A PERMIT is required as a prerequisite, in accordance with the provisions of Section II of this regulation, for any operation involving the delivery of oil by truck tanks or by transports to or from any point within the State of Maryland.

### B. CERTIFICATION OF DRIVERS OF TRANSPORTS:

(1) An OIL VEHICLE OPERATOR'S CERTIFICATE is required of drivers of transports engaged in the delivery of oil.

(2) OIL VEHICLE OPERATOR'S CERTIFICATES shall be issued by the Administration only after a holder of a PERMIT submits, in writing, to the Administration sufficient evidence showing that the person for whom the certificate is requested has received adequate training in the procedures employed for the safe handling of oil, the prevention of oil spills, and the containment and removal of spilled oil.

### C. REQUIREMENTS FOR OIL DELIVERY:

Drivers of transports and truck tanks shall be instructed by the permit holder regarding the following measures designed to reduce the likelihood and effects of an oil spill while delivering oil:

(1) Drivers shall stand at the location of the delivery receptacle in full control of the nozzle shut off at all times when loading or unloading oil. If for any reason the driver is compelled to leave the equipment unattended, all valves, pumps and safeties of the dispensing vehicle, as well as those of the receiving facility, shall be turned off or returned to the closed position.

(2) Drivers shall remain alert while the transfer is in progress and they shall report immediately to their employer or supervisor any unusual condition involving the transfer operation, such as spills, any obvious discrepancies between the quantities delivered and received, or the existence of any equipment defects or unsafe delivery conditions.

(3) Drivers shall use proper hoses and fittings in the delivery of the oil, and shall make sure that all hose connections are tight before commencing the delivery.

D. AUXILIARY ALARM SYSTEMS:

High liquid level gauges, alarms or tank overflow shall be accessible, audible or visible to the person making the delivery, in addition to other spill emergency warning systems acceptable to the Administration.

E. REQUIREMENTS FOR EQUIPMENT USED IN OIL DELIVERY:

(1) Hoses shall be of a grade suitable for the type of oil product delivered (suction, pump or gravity discharge).

(2) Transfer hoses, when used in connection with a pumping operation, shall be wire reinforced and rated at a minimum of 75 p.s.i.

(3) Hoses shall be designed to withstand pressure of the shut off head of the cargo pump or pump relief valve setting.

## SECTION VI. Oil Transfer Facilities

A. OPERATIONS REQUIRING PERMIT:

A PERMIT is required, in accordance with the provisions of this regulation (Section II), for the operation of an on-shore facility when it involves the transfer of oil to or from any truck tank, transport or tank car.

B. REQUIREMENTS FOR SPILL CONTROL:

(1) Containment curbs, trenching or other reasonable spill control system shall be used for tank car and tank truck transfer areas. Any oil spilled within the containment area shall be removed immediately and disposed of in a manner and location approved by the Administration. Containment facilities shall be designed so as to prevent the entrance of surface runoff.

(2) Any wastewaters contaminated with oil leaving the containment area, and capable of reaching the waters of the State, shall be passed through an approved pollution control system.

C. AVAILABILITY AND USE OF CLEAN-UP MATERIALS:

Clean-up materials, such as sorbents, shall be available at the site of the facility for use in the cleanup and removal of spilled oil and shall be used in the event of oil spills.

## SECTION VII. Facilities for the Handling of Used Oil

A. OPERATIONS REQUIRING PERMIT:

A PERMIT is required, in accordance with the provisions of Section II of this regulation, for facilities involving the handling, reuse, processing, reprocessing, or disposal of any oils that have previously been used.

B. REQUIREMENTS FOR OIL SEPARATING FACILITIES:

(1) At any facility where used oil is collected, separated or contained, a suitable oil separating system shall be maintained in proper operating condition and checked regularly for evidence of equipment failure or malfunctioning. Immediate corrective measures shall be undertaken in the event of equipment failure or malfunctioning.

(2) All sewers and drains receiving oil-bearing wastes or wastewaters from operations or locations where oil is used or handled, shall be provided with adequate and properly maintained oil separating systems.

C. ULTIMATE DISPOSAL OF WASTE OIL:

The ultimate disposal of waste oil shall be undertaken in a manner that will avoid stream pollution. Approved disposal practices are salvaging or sale to a salvage company, use as fuel, use as a binder for unpaved roads, parking areas, etc.

D. REQUIREMENTS FOR USED OIL STORAGE:

Any person collecting or handling used oil shall provide suitable storage facilities to hold such oil for proper disposal. The location and physical features of such storage facilities shall be such as to eliminate the threat of pollution of either surface or ground waters.

E. USED OIL FROM VESSELS:

Steaming and washing of tanks while vessels are in Maryland waters shall be conducted only when the vessels are equipped with "slop" holding tanks or when these vessels are moored at docks with facilities for receiving all of the discharge from the steaming and washing in storage facilities, or where sludge barge service is available.

## SECTION VIII. Garages, Service Stations and Similar Oil Handling Facilities

A. OPERATIONS REQUIRING PERMIT:

A PERMIT is required, in accordance with the provisions of Section II of this regulation, for vehicle maintenance shops and similar facilities where small amounts of oil are handled in the course of normal operations.

B. REQUIREMENTS FOR OIL SEPARATING FACILITIES:

All sewers and drains serving these facilities, and receiving oil-bearing wastes or wastewaters from operations at these facilities, shall be provided with adequate and properly maintained oil separating systems.

C. SEPARATE DRAINAGE SYSTEM REQUIRED:

Drains receiving oil wastes from operations at these facilities shall be entirely separate from any other drain pipe of the plumbing system.

D. ULTIMATE DISPOSAL OF WASTE OIL:

The ultimate disposal of waste oil shall be undertaken in a manner that will avoid stream pollution, such as salvaging or sale to a salvage company, use as fuel, use as a binder for unpaved roads, parking areas, etc.

## SECTION IX. Effect on Other Governmental Regulations

These regulations are not intended to and shall not relieve the permittee of the duty to comply with all other valid governmental regulations governing activities regulated hereunder, including, but not limited to, regulations of the State Fire Marshall; the Maryland Public Service Commission; the Maryland Motor Vehicles Administration; the Pipeline Safety Division of the National Transportation Safety Board; U. S. Department of Transportation; and other appropriate State, Federal and local agencies.

# APPENDIX II-C

## MASSACHUSETTS GENERAL LAWS ANNOTATED

## Chapter 21

### SECTION 52. Waste Oil Disposal; Permits

No one shall engage in the business of collecting waste oil or shall dispose of waste oil in any waters of the commonwealth, without a permit from the division. Said permit shall not be granted unless the division is satisfied that such disposition will not result in further pollution.

The division shall consult with and advise persons engaged or intending to engage in the business of disposing of waste oil as to the most appropriate and best method of disposal. It shall conduct a program of study and research and demonstration, relating to new and improved methods of waste oil disposal.

### SECTION 53. Short title; Investigation and Prosecution of Violations

Sections twenty-six to fifty-three, inclusive, shall be known and referred to as the Massachusetts Clean Waters Act and the officers of the division of law enforcement shall, upon request of the water resources commission, investigate and prosecute violations of law, orders or rules and regulations relating to said act.

### SECTION 57. Chemical and Other Hazardous Wastes; Handling and Disposal of

The members of the water resources commission individually and the commissioner of the department of public safety shall sit as a board for the purpose of insuring that certain chemical and other hazardous wastes are safely and properly handled and disposed of. Said board shall investigate the handling and disposal of said wastes and shall coordinate the activities of the agencies represented by the members of said board.

Where said board finds that the powers delegated to said agency are insufficient, it shall have the power to adopt such rules and regulations as may be necessary to protect the public and its environment from the effects of unregulated handling and disposal of said wastes. The board shall delegate to the most appropriate agency represented by its members responsibility for the administration of its regulations. Nothing in this section or section fifty-eight shall diminish or interfere with the responsibilities of any other agency.

Said board shall, after a public hearing, adopt rules and regulations -

1. identifying substances which, because of their chemical, radioactive, flammable, explosive or other characteristics, constitute or may reasonably be expected to constitute a danger to the public health, safety or welfare or to the environment and which should be handled and disposed of only by licensed hazardous waste disposers. Mercury, beryllium, compounds thereof, and such other elements and compounds as may be listed from time to time by said board, shall not be dumped in any of the waters of the commonwealth;

2. specifying in what manner said wastes may be handled or disposed of, requiring that various types of said wastes be segregated from one another, be neutralized or otherwise rendered harmless prior to disposal and be suitably contained;

3. specifying the location at which said substances may be disposed of both within or without the commonwealth in order to prevent damage to any natural resource utilized or enjoyed by the public, or to the environment;

4. establishing reasonable exceptions when competent scientific evidence satisfies the board that the substances and quantities involved do not constitute a threat to the public and its environment;

5. setting reasonable license and inspection fees; and

6. such other rules and regulations as may be necessary to carry out the purposes of this section and section fifty-eight.

### SECTION 58. Handling and Disposal of Hazardous Wastes; Licensing of

No person including the originator thereof shall handle or dispose of such hazardous wastes as are specified by said board without a license from the division of water pollution control. Said license shall be subject to such terms and conditions as the division deems advisable in accordance with the regulations adopted by said board, including the condition that such handling or disposal receive the specific approval of one or more of the agencies reprepresented by the members of said board.

A violation of this section or of section 57 or any regulation adopted thereunder shall be punished by a fine of not more than five thousand dollars, or by imprisonment in a jail or house of correction for not more than six months, or both. The superior court shall have jurisdiction in equity to enforce the provisions of said sections and to remedy any violations thereof, including injunctive relief.

## Appendix II-D

(From Congressional Record - March 20, 1972. Inserted by Senator J. Caleb Boggs from an article in summer 1971 issue of Ecology Law Quarterly by W.A. Irwin, Univ. of Mich. and W.E. Borhenne, Secretary General-elect, Inter-Parliamentary Working Center, Bonn, Germany.)

## 1968 WASTE OIL LAW - FEDERAL REPUBLIC OF GERMANY

(Law Concerning Measures to Assure the Disposal of Waste Oil (Waste Oil Law) of 23 December 1968 (I Bundesgesetizbatt 1419)(translated by Author))

The Federal Parliament has passed the following law:

### Part One: The economical assurance of waste oil disposal

§ 1. Reserve Fund

(1) To assure the economical disposal of waste oil, a special federal fund is created with the name "Reserve Fund for Assuring Disposal of Waste Oil" (Reserve Fund).

(2) The Federal Office for Trade and Industry (Federal Office) is responsible for administering the Reserve Fund. The costs of administration are to be paid from the fund.

(3) The funds may otherwise only be used for payments according to § 2 (1) of this law.

§ 2. Purpose

(1) Trade and other economic enterprises as well as public-law juristic persons located within the jurisdiction of the law which dispose of waste oils collected from others according to § 3(3) may receive payments for those costs not otherwise covered, if the waste oils are disposed of without harm to waters or soil and if air pollution, from which the general public and the neighborhood should be protected, does not arise. The Federal Minister for Economic Affairs, with the agreement of the Federal Minister for Health Affairs and in consideration of economic factors, shall determine by regulations what disposal methods, including regeneration, and what minimum level of continual payments may be used.

(2) The payments will be made by the Federal Office according to guidelines established by the Federal Minister for Economic Affairs. These guidelines should especially insure that:

1. the recipients of the payments obligate themselves to collect the waste oils according to § 3 in districts determined by the Federal Office or to prepare for later pick-up;

2. collection and transportation costs are part of the disposal costs;

3. in the payment rates for the individual disposal methods, the costs caused by collection conditions of above-average difficulty shall be specially compensated;

4. the payments at most correspond to the unincluded costs which on the average arise for an enterprise of the same kind;

5. payments for regenerated oil products made from waste oils (re-refined products) are to be paid back insofar as the products are exported to other member nations of the European Economic Community;

6. the requirements of the Reserve Fund are to be kept as low as possible under the previous principles.

(3) The payment rates established by the guidelines shall remain unchanged for the first two years after this law becomes effective; thereafter they may be changed yearly at the beginning of a calendar month after six months prior notice.

(4) The Federal Government shall report to the Federal Parliament on the activity of the Reserve Fund by the 31st of March of every third year, for the first time on March 31, 1972, especially on the possibilities of a reduction of the continued payments (§ 2(1) and the compensation tax (§2(1)) and the compensation tax ( § 4(2)).

§ 3. Collection of Waste Oil

(1) Those within the area of validity of this law who possess waste oils may require of the Federal Office that:

1. their waste oils be collected in quantities over 200 liters, insofar as the necessary facilities for the collection and harmless disposal of waste oil exist;

2. for amounts less than 200 liters, later collection will be provided for.

(2) Waste oils within the meaning of § 3(1) are used mineral oils and used liquid mineral oil products as well as wastes from storage, business and transportation receptacles containing mineral oil.

(3) Waste oils shall be collected free of charge according to § 3(1). The Federal Minister for Economic Affairs is empowered to issue regulations concerning:

1. the identification and measurement of the collected materials;

2. the permissible proportion of foreign substances, which may not exceed fifteen percent.

(4) Quantities of foreign substances in excess of the permissible proportion (§ 13(3) Number 2) shall be picked up for a fee. The fee shall correspond to the price list filed with the Federal Office by enterprises obligated to collect waste oils.

(5) Those possessing waste oils remain liable for harm caused by failure to notify others of foreign substances in the waste oils.

§ 4 The Compensation Tax.

(1) The Reserve Fund shall be supported by a compensation tax.

(2) The following dutiable goods

1. Lubricating oils from Number 27.10-C-III of the customs tariff schedule;

2. gas oils from Number 27.10-C-I of the customs tariff schedule, to the extent they are used as lubricating oils;

3. greases with their heavy oil components; are all subject to the compensation tax insofar as they are subject to the oil tax according to the Oil Tax Law of 1964 as published on 20 December 1963 (I Bundesgesetzblatt 1003) and last amended by the Law Amending Penal Provisions of the Federal Tax Law and other Laws of 10 August 1967 (I Bundesgesetzblatt 877). The compensation tax amounts to 7.50 Deutsche Mark per 100 kilograms of dutiable goods. The Federal Minister for Economic Affairs is empowered to reduce the compensation tax rate by regulation to the extent that the requirements of the Reserve Fund allow.

(3) The liability for the compensation tax arises when the oil tax liability for the dutiable goods becomes unconditional.

(4) The compensation tax is payable by the person liable for the oil tax.

(5) If dutiable goods are withheld or withdrawn from customs supervision of the compensation tax is due immediately. Otherwise the person liable for the compensation tax must pay the amount which has accrued during the course of a calendar month no later than the 10th of the second month following without being requested to do so.

(6) The compensation tax is collected by the Federal Office. The Federal Minister for Economic Affairs is empowered to issue by regulation the required provisions concerning the levying and collection of the compensation tax. Customs officials shall provide the Federal Office with the information necessary for the administration of the compensation tax and shall make the required documents available to the Federal Office.

§ 5. Information

(1) The person liable for the compensation tax must furnish the Federal Office the information and documents needed for the implementation of this law and the regulations issued under it.

(2) Employees and agents of the Federal Office and employees of the customs administration are authorized within the scope of § 5(1) to check dutiable goods, to enter property, business installations and offices, and, for the prevention of imminent danger to public safety and order, also the living quarters of the person required to furnish information, to make inspections and tests there and examine business records of the person required to furnish information. The basic right of the Article 13 of the Constitution concerning the inviolability of a residence is to this extent limited.

(3) The person required to furnish information may refuse to do so for questions whose answers would expose himself or one of the relatives listed in § 383(1) Numbers 1-3 of the Civil Procedure Law to the danger of criminal prosecution or a proceeding under the Law Concerning Violations of Regulations.

(4) If a person required to provide information refuses to furnish information or relevant documents according to § 5(1), the Federal Office may establish the conclusions necessary for determining the compensation tax by way of estimates.

## Part Two: Supervising the Location of Waste Oil

§ 6. The Duty to Keep Records

(1) Trade and other economic enterprises must keep a record book for each business in which at least 500 kilograms of waste oils within the meaning of § 6(2) accumulate or in which a yearly accumulation of waste oils of this amount may be reckoned with. The same applies to trade and other economic enterprises which accept at least this amount yearly of waste oils of this kind. The official responsible under state law may upon application

1. approve centralized maintenance of records in a main office if the supervision of the whereabouts of the waste oils will not be thereby disadvantaged;

2. relieve one of the duty to keep a record book if, because of its nature and management, the enterprise can be adequately supervised without a record book.

(2) Waste oils within the meaning of this provision are those substances named in § 3(2), insofar as

1. their collection is not required under § 3(1);

2. they are mixed with foreign substances whose amounts

exceed the permissible proportion under § 3(3) Number 2.

(3) The kind, amount and whereabouts of the waste oils are to be continually entered in the record books. The details concerning the set-up and keeping of the record book, the retaining of receipts and the periods of safekeeping of the records shall be governed by regulations issued by the Federal Minister of Health Affairs in cooperation with the Federal Minister of Economic Affairs.

§ 7. Supervision.

(1) Trade and other economic enterprises as well as public law juristic persons which accumulate waste oils within the meaning of § 3(2) or accept waste oils of this kind must upon request furnish the official responsible under state law the information required to supervise the whereabouts of the waste oils. § 5(3) applies accordingly.

(2) The persons commissioned by the responsible official with gathering information are authorized within the scope of § 7(1) to enter property, installations, and business offices and, for the prevention of imminent danger to public safety and order, also the living quarters of the person required to furnish information, to make tests and inspections there, to take samples, and to examine the business records of the person required to furnish information. The basic right of Article 13 of the Constitution concerning the inviolability of a residence is to this extent limited.

(3) Record books and receipts under § 6 must be presented or delivered upon request to responsible officials for examination.

(4) The information and documents obtained under § 7(1), (2), and (3) may not be used in a tax proceeding, a criminal proceeding involving a tax offense or a fine proceeding involving a tax violation. The provisions of §§ 175, 179, 188(1) and 189 of the Federal Tax Law concerning the duties to assist and give notice to the financial authorities do not apply to this extent.

§ 8. Exception

(1) §§ 6 and 7 of this law do not apply.

1. to lake and river transport businesses;

2. to the Federal Railways and the Federal Post Office;

3. to federal installations which serve sovereign purposes and do not fall within § 28(1) Number 2.

(2) The Federal Minister for Traffic is empowered, in agreement with the Federal Minister for Health Affairs, to issue regulations with provisions for lake and river transport concerning the collection of the waste oils named in § 3(2) from watercraft and floating installations, in particular concerning:

1. the duty to deliver waste oils at specific intervals to an enterprise obligated to collect (§ 3) or to a collection place approved by a responsible official;

2. the record of delivery and the safekeeping of these records; and

3. the supervision of the collection and delivery of the waste oils.

(3) The International Treaty on the Prevention of the Pollution of the Sea by Oil of 1954 as well as the legal provisions promulgated in accordance with the Law Concerning the International Treaty on the Prevention of the Pollution of the Sea by Oil of 1954 of 21 March 1954 (II Bundesgesetzblatt 379) remain undisturbed.

## Part Three: Penalty and Fine Provisions

### § 9. Breach of Professional Secrecy

(1) Anyone who reveals without authorization another's secret, especially a trade or business secret, which became known to him in his capacity as employee or agent of one of the officials assigned a duty on the basis of this law will be punished by imprisonment up to one year or a fine or both.

(2) If the perpetrator acts for money or with the intention to enrich himself or another or to injure another, the penalty may be up to two years' imprisonment; in addition a fine may be imposed. These punishments also apply to one who converts another's secret, especially a trade or business secret, which became known to him under the conditions of §9(1), into money without authorization.

(3) The crime will only be prosecuted upon application of the party injured.

### §10. Imposition of Fines

(1) It is a violation of a regulation intentionally or negligently to

1. fail to keep a record book, contrary to §6(1);

2. fail to furnish information or fail to furnish it correctly, completely or timely, contrary to § 7(1);

3. refuse to permit tests, inspections, the examination of business records or the taking of samples, contrary to §7(2);

4. fail to present or deliver record books or receipts, contrary to § 7(3); or

5. contravene a regulation issued on the basis of § 6(3) or § 8(2), if it imposes a fine governed by this section on particular acts or omissions.

(2) A violation of regulations may be punished with a fine of up to 10,000 Deutsche Mark.

## Part Four: Transition and Concluding Provisions

### § 11. Transition Provisions

(1) Dutiable goods (§ 4(2)) for which the oil tax became unconditional before this law became effective are subject to the compensation tax, with the exception of those which are in the hands of consumers, service stations or auto repair shops. The tax liability arises when the law becomes effective. The person who is liable for the tax is the possessor of the goods. For goods en route the liability transfers to the recipient with the transfer of ownership.

(2) The person liable for the tax must declare the dutiable goods to the Federal Office in writing within four weeks after this law becomes effective. Payment of the tax is due without request four weeks after the declaration; for goods not properly declared it is due at the expiration of the declaration period.

### § 12. Validity in the State of Berlin

This law is valid according to § 13(1) of the Third Transition Law of 4 January 1952 (I Bundesgesetzblatt 1) in the State of Berlin also. Regulations issued on the basis of this law are valid in the State of Berlin according to § 14 of the Third Transition Law.

### § 13. Effectiveness of the Law

(1) § 3(1), (2), (3) Sentence 1, and (4) become effective 1 July 1969. § 6(1) becomes effective on the first day of the calendar year following the publication of the regulations based on § 6(3).

(2) Otherwise this law becomes effective on 1 January 1969.

## APPENDIX II-E

92d CONGRESS
2d Session

H.R. 15502

IN THE HOUSE OF REPRESENTATIVES

June 14, 1972

Mr. Vanik introduced the following bill; which was referred to the Committee on Ways and Means

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## A BILL

TO PROVIDE FOR THE RECYCLING OF USED OIL AND FOR OTHER PURPOSES.

Be it enacted by the Senate and House of Representatives of the United States in Congress assembled, that this Act may be cited as the "National Oil Recycling Act".

### PURPOSES

SEC. 2. Congress finds that hundreds of millions of gallons of used oil are being wasted each year, and are being disposed of in ways which pollute the waters, air, and land of the United States. For the purposes of -

(1) protecting the health and welfare of the people of the United States;

(2) restoring, preserving, and enhancing the Nation's environment; and

(3) conserving oil for the national defense; Congress declares that to the greatest extent possible consistent with this Act and other Federal law, used oil shall be recycled.

### DEFINITIONS

SEC. 3. For the purposes of this Act -

(1) the term "used oil" means all oil which has through use been contaminated by physical or chemical impurities which have not been removed by subsequent re-refining or other processing;

(2) the term "recycled oil" means used oil which has been re-refined or otherwise processed to remove the physical and chemical contaminants acquired through use, which by itself or when blended with new oil or additives is substantially identical or superior to new oil intended for the same purposes;

(3) the term "new oil" means all oil which has been refined from virgin oil and may or may not contain additives, but has never been used. The term "new oil" does not include "used oil" and "recycled oil" defined in subsections 3 (1) and 3 (2);

(4) the term "lubricating oil" means all oil regardless of origin, which -
(A) is suitable for use as a lubricant, or
(B) is sold for use as a lubricant;

(5) the term "hydraulic oil" means all oil which is used primarily to transmit power or pressure, but which may also serve lubricating and other functions;

(6) the term "cutting oil" means all oil which is used primarily in cutting, milling and machining operations (including forging, drawing, rolling, shearing, punching, and stamping), but which may also serve lubricating and other functions;

(7) the term "fuel oil" means all oil which has been refined, re-refined, or otherwise processed for the purpose of being burned to produce heat;

(8) the term "automotive oil" means all oil, including lubricating oil and hydraulic oil, which is used in automobiles, trucks, buses, motorcycles, and all other motor vehicles which travel on roads and highways;

(9) the term "industrial oil" means all oil exclusive of virgin oil, fuel oil, oils for cooking and medicinal purposes, and automobile oil. Industrial oil includes, but is not limited to, lubricating oil, hydraulic oil, and cutting oil when such oils are not automotive oils;

(10) the term "used oil collector" means any person who controls a system which functions to retrieve or collect used oil for sale or transfer to oil recycling facilities, or for other methods of disposal;

(11) the term "used oil recycler" means any person who re-refines or otherwise processes used oil to remove its physical and chemical contaminants.

## TAX PROVISIONS

SEC. 4. (a) The Internal Revenue Code of 1954, Subpart B-Lubricating Oil, is amended to read as follows:

"SEC. 4091. IMPOSITION OF TAX.

"There is hereby imposed on lubricating, hydraulic, and cutting oils (other than recycled oils) which are sold in the United States by the manufacturer or producer a tax of 6 cents per gallon, to be paid by the manufacturer or producer.

"SEC. 4092. DEFINITIONS

"(a) CERTAIN VENDEES CONSIDERED AS MANUFACTURERS.- For the purposes of this subpart, a vendee who has purchased lubricating, hydraulic, or cutting oils free of tax under section 4093 shall be considered the manufacturer or producer of such oils.

"(b) LUBRICATING OIL.- The term 'lubricating oil' means all oil regardless of origin, which -

"(1) is suitable for use as a lubricant, or

"(2) is sold for use as a lubricant.

"(c) HYDRAULIC OIL.- The term 'hydraulic oil' means all oil which is used primarily to transmit power or pressure, but which may also serve lubricating and other functions.

"(d) CUTTING OIL.- The term 'cutting oil' means all oil which is used primarily in cutting, milling, and machining operations (including forging, drawing, rolling, shearing, punching, and stamping), but which may also serve lubricating and other functions.

"(e) RECYCLED OIL.- The term 'recycled oil' means used oil which has been re-refined or otherwise processed to remove the physical and chemical contaminants acquired through use, which by itself or when blended with new oil or additives is substantially identical or superior to new oil intended for the same purposes.

"SEC. 4093. EXEMPTION OF SALES TO PRODUCERS.

"Under regulations prescribed by the Secretary or his delegate, no tax shall be imposed under this subpart upon lubricating, hydraulic, or cutting oils sold to a manufacturer or producer of such oils for resale by him."

(b) Section 4094 of the Internal Revenue Code of 1954 (Subpart B-Lubricating Oil, cross reference) is hereby repealed.

(c) Section 6424 of the Internal Revenue Code of 1954 (providing off-highway users of lubricating oils with a tax refund of 6 cents per gallon) is hereby repealed.

FEDERAL ENCOURAGEMENT OF THE USE OF RECYCLED OIL

SEC. 5. All Federal officials shall act within their authority to encourage the use of recycled oil. Such action includes, but is not limited to -

(1) procuring recycled automotive and industrial oils for all military and nonmilitary Federal uses, whenever such recycled oils are available at prices competitive with those of new oil produced for the same purposes;

(2) requiring all persons contracting with the Federal Government to use recycled oil in performing such contracts, whenever recycled oils are available at prices competitive with those of new oil produced for the same purposes;

(3) educating the Government and private sectors of the economy as to the merits of recycled oil, and the need for its use in order to reduce the drain on the Nation's oil reserves and minimize the disposal of used oil in ways harmful to the environment;

(4) where necessary, assisting and encouraging the development of performance standards and specifications, and systematic and economical testing procedures to facilitate the comparison of recycled oil with new oil.

## STATE REGULATION AND ENCOURAGEMENT

SEC. 6. (a) This Act shall in no way preempt State regulation of recycled oil or used oil disposal whenever such regulation provides for stricter control of recycled oil or used oil than provided for by Federal law.

(b) The States shall encourage the use of recycled oil in order to accomplish the purposes of this Act. In order to qualify for Federal grants under section 12 of this Act, States shall adopt laws, regulations, and administrative machinery which shall provide for, but not be limited to -

(1) requiring that used oil collectors obtain State permits prior to engaging in used oil collecting activities. Such permits shall require as a minimum information pertaining to methods for collecting, storing, transferring, and disposing of used oil, as well as the identity of used oil sources, purchasers, transferees, and disposal sites;

(2) requiring that used oil recyclers obtain State permits prior to engaging in recycling operations. Such operating permits shall require as a minimum information identifying -

(A) the sources and quantities of used oil to be acquired for recycling;
(B) the recycling facility's plant size and operating capacity;
(C) the specific recycling technologies to be utilized;
(D) the quantities and grades of recycled oil to be produced; and

(E) the methods of disposing of the waste byproducts;

(3) when recycled oil is available at prices competitive with new oil, using recycled oil for all automotive and industrial uses of the State government, and requiring all parties contracting with the State to use recycled oil in the performance of such contracts;

(4) regulating the retail sales of automobile oil not covered by Section 8 of this Act so as to encourage the recycling of used oil;

(5) prohibiting the use of used oil as fuel oil or for the oiling of State roads, unless such oil has been processed to meet the minimum standards for such uses established by Federal and State pollution control laws;

(6) educating the public and private sectors of the State as to the merits of recycled oil, and the need for its use in order to reduce the drain on the nation's oil reserves and minimize the disposal of used oil in ways harmful to the environment.

## LABELING OF OIL

SEC. 7. (a) All recycled oil shall bear on the front panel of the container in which such oil is packaged for sale the inscription "RECYCLED OIL" clearly and prominently placed. All automotive and industrial oil, both new and recycled, shall bear on the container in which such oil is sold the inscription, "It is in the national interest to recycle this product after use."

(b) The Administrator of the Environmental Protection Agency shall promulgate regulations requiring all containers of automotive and industrial oil, both new and recycled, to bear labels relating to the proper disposal of such oils after use.

## RETAIL SALES OF AUTOMOTIVE OIL

SEC. 8. (a) Automotive oil packaged for sale for selfservice or carry away by the consumer shall be sold in resealable containers capable of holding used oil without spillage.

(b) All persons making resealable container sales shall collect a customer deposit of $0.10 per resealable container regardless of size. This deposit shall be refunded upon return of the container, either containing used oil or empty.

(c) All persons who sell automotive oils shall maintain used oil collection facilities on their premises. Such facilities shall -

(1) be of sufficient size and capacity to handle all customer

returns of used oil and used oil containers; and

(2) be serviced on a regular basis by used oil collectors who dispose of such used oil in a manner not in contravention to this Act.

## RESTRICTIVE CONTRACTS PROHIBITED

SEC. 9. (a) It shall be unlawful for any person to enter into any contract or agreement where the intent of such contract or agreement is to discourage the recycling of used oil.

(b) Violations of subsection (a) are subject to a fine of $50,000 for each violation thereof, or imprisonment for a term not to exceed one year, or both.

## RECORDS

SEC. 10. (a) Users of more than 100 gallons of industrial oil per year shall maintain complete records of -

(1) the quantities and types of all oils purchased for industrial use;

(2) the quantities and types of all industrial oils consumed during use; and

(3) the quantities and types of all industrial oils disposed of after use -

(A) by in-house recycling;
(B) by delivery to or pickup by used oil collectors or used oil recyclers; or
(C) by any other method of disposal.

(b) Used oil recyclers shall maintain complete records of -

(1) the quantities and types of all used oil acquired;

(2) the quantities and types of all new oil acquired for use in blending recycled oil;

(3) the quantities, types, and sources of sale or other disposal of all recycled oil produced; and

(4) the quantities, types, and places of disposal of all waste by-product generated in the recycling process.

(c) Used oil collectors shall maintain complete records of -

(1) the quantities and types of used oil collected; and

(2) the quantities and types of used oil -

  (A) delivered to recyclers; and
  (B) otherwise disposed (including the place of disposal).

(d) Records required to be kept by this section or any other provision of this Act shall be kept in accordance with regulations promulgated by the Secretary of the Treasury, the Secretary of Commerce, and the Administrator of the Environmental Protection Agency.

## REPORTS

SEC. 11. The Administrator of the Environmental Protection Agency shall make reports to Congress no later than March 31 of each year, such reports containing, but not limited to, the following information -

(1) the amount of automotive and industrial oil sold throughout the United States each year;

(2) the amount of used oil recycled each year;

(3) the significance of used oil as a contributor to water pollution and other environmental problems; and

(4) the problems of the oil recycling industry (including new technological requirements and necessity for tax incentives).

## MANDATORY LICENSING

SEC. 12. Whenever the Administrator of the Environmental Protection Agency determines -

(1) that -

  (A) in implementing the provisions of this Act, a United States patent right not otherwise available is necessary to enable any person to comply with this Act; and
  (B) there are no reasonable alternative methods to accomplish this Act's purposes, and

(2) that the inavailability of such patent right may result in a substantial lessening of competition or a tendency to create a monopoly in any line of the Nation's commerce, the Administrator, through the Attorney General, may so certify to a district court of the United States, which may order the person owning the patent to license it on such reasonable terms as the court, after hearing, may determine.

## PENALTIES AND ENFORCEMENT

SEC. 13. (a) Violations of section 4 shall be punished as provided for by the Internal Revenue Code of 1954 (as amended). Violations of section 9 (Restrictive Contracts Prohibited) shall be punished as provided for in section 9. Any person violating any provision of this Act which does not provide for specific penalties or punishment thereunder shall be subject to a civil fine not to exceed $25,000 for each violation, or be guilty of a misdemeanor punishable by six months in a Federal penitentiary for each violation, or both.

(b) It shall be the duty of the United States Attorney General and his representatives, United States attorneys, to prosecute violations of this Act. In the event that the Federal Government fails to fulfill its duty of enforcement under this Act, any citizen may bring an action in his or her name to enforce this Act without regard to any amount of alleged damages.

## GRANTS AND APPROPRIATIONS

SEC. 14. (a) There is hereby authorized to be appropriated for the fiscal year ending June 30, 1973, and for each succeeding fiscal year, $25,000,000 for grants to the States to assist them in fulfilling the purposes and provisions of this Act. The Administrator of the Environmental Protection Agency shall make allotments to the States, not to exceed 10 cents per capita for any State based on the latest national census, when he has determined that they are in compliance with this Act. The Administrator may prescribe regulations, pursuant to this Act, governing the expenditure of the allotments.

(b) There is hereby authorized to be appropriated for the fiscal year ending June 30, 1973, and for each succeeding fiscal year through the fiscal year ending June 30, 1976, $10,000,000 for the development of new processes and technology to be used in the economical and ecological recycling of used oil. The Administrator of the Environmental Protection Agency may make grants of this money, pursuant to regulations and requirements he shall adopt, to private parties, or use this money within the Environmental Protection Agency for the above purposes.

(c) There is hereby authorized to be appropriated for the fiscal year ending June 30, 1973, and for each succeeding fiscal year, through the fiscal year ending June 30, 1976, $5,000,000 for the development of standards and testing methods to facilitate the comparison of recycled oil with new oil. The Secretary of Commerce may make grants of this money, pursuant to regulations and requirements he shall adopt, to private parties, or use this money within the Department of Commerce for the above purposes.

## EFFECTIVE DATA

SEC. 15. Section 9 (Restrictive Contracts Prohibited) of this Act is effective immediately upon this Act becoming law. Section 4 (Tax Provisions) of this Act becomes effective on the first day of the calendar quarter following the day this Act becomes law. All other provisions of this Act become effective ninety days after this Act becomes law.

# Appendix III

## LIST OF COMMERCIAL RE-REFINERS

(September 1971)

### ARIZONA

Kaibab Industries, Inc.
Aldous V. Steen
2600 South 20th Avenue
Phoenix, Arizona 85009

### ARKANSAS

Henley Oil Company
Norfleet, Ark.

### CALIFORNIA

A. Ray Banks
Palmer Odegard
Bayside Oil Corp.
977 Bransten Road
San Carlos, Calif. 94070

George Leach
Leach Oil Company, Inc.
625 East Compton Blvd.
Compton, Calif. 90220

H.B. Millard
Motor Guard Lubricants Co.
4334 East Washington Blvd.
Los Angeles, Calif. 90023

Charles R. Nelson
Pacific Petroleum Co.
Michael D. Marcus
Economy Refining and Service
7929 San Leandro St.
Oakland, Calif. 94621

A.W. & Roy Talley
Talley Bros., Inc.
2007 Laura Avenue
Huntington Park, Calif. 90255

Otis F. Humphrey
Nelco Oil Refining Company
1211 McKinley Avenue
National City, Calif. 92050

### COLORADO

Lloyd Cunningham
Williams Refining Company
5901 North Federal
Denver, Colorado 80221

### FLORIDA

George Davis
Davis Oil Company
Box 1303
Tallahassee, Florida 32302

John Schroter
Peak Oil Company
Route 3, Box 24
Tampa, Florida 33619

Sol Blair
Petroleum Products Company
Box 336
Hallendale, Florida

Seaboard Oil Industries of Fla., Inc.
Jack Blase
Box 6336
Jacksonville, Florida

### GEORGIA

Jack Blase
Seaboard Industries
Box 47333
Doraville, Georgia 30040

### ILLINOIS

Belton Williams
Motor Oils Refining Company
7601 West 47th Street
Lyons, Illinois 60534

Jim L. Pierce
Sorco Oil & Refining Company
Div. of Cam-Or., Inc.
1925 E. Madison
Springfield, Ill. 62702

## INDIANA

Charles Bates
Bates Oil & Refining Company
Box 267
Chandler, Ind.  47610

Andrew Carson
Box 587
Westville Oil Company
Westville, Ind.  46391

John W. Swain, Jr.
Alvord Oil Company
1509 S. Senate Avenue
Indianapolis, Ind.  46225

## IOWA

Norman R. Schlott
U.S. Oil Works
116 - 29th Avenue
Council Bluffs, Iowa
Mail:  727 South 13th St.
       Omaha, Nebr.  68102

## KANSAS

Robert O'Blasny
Coral Refining Company
765 Pawnee Avenue
Kansas City, Kansas  66105

M.C. McDonald
McDonald Oil Company
1603 S. Walnut
Coffeyville, Kansas

Ava Johns
Super-Refined Oil Co.
915 East 21st St.
Wichita, Kansas  67214

## MICHIGAN

Jack W. Epstein
Dearborn Refining Company
3901 Wyoming Avenue
Dearborn, Michigan  48120

## MINNESOTA

A.L. Warden
Warden Oil Company
187 Humboldt Avenue North
Minneapolis, Minn.  55405

## MISSISSIPPI

H.K. Robertson
Jackson Oil Products Company
Box 5686
Jackson, Miss.  39208

## MISSOURI

F.A. Gettinger
Glen Gettinger
Midwest Oil Refining Company
1900 Walton Road
St. Louis, Mo.  63114

## NEBRASKA

Marvin Walenz
Monarch Oil Company
Box 1257
E. Omaha, Nebr.

## NEW JERSEY

Martin Morrison
Diamond Head Oil Refining Company
1427 Harrison Tpke.
Kearney, New Jersey

Solfred Maizus
National Oil Recovery Corp.
Box 338
Bayonne, New Jersey

## NEW YORK

Geo. T. Booth & Son, Inc.
76 Robinson St.
No. Tonawanda, N.Y.  14120

## NEW YORK (cont.)

Northeast Oil Company
R.W. Mahler
327 Edwards Drive
Fayetteville, New York

Louis Strick
Triplex Oil Company
37 - 80 Review Avenue
Long Island City, N.Y. 11101

## NORTH CAROLINA

Jack Blase
Seaboard Industries, Inc.
South Oil Division
Box 106
Greensboro, N.C. 27402

## OHIO

Jac Fallenberg
Alan Gressel
Research Oil Refining Company
3680 Valley Road
Cleveland 9, Ohio

S.R. Passell
Keenan Oil Company
2350 Seymour Avenue
Cincinnati, Ohio 45212

## OKLAHOMA

Frank Kerran
Cameron L. Kerran
Double Eagle Refining Company
Box 11257
Oklahoma City, Okla. 73111

Edward Kitchen
Kitchen Oil Company
Stroud, Okla.

## OREGON

A.L. Geary
Nu-Way Oil Company
7039 NE 46th Avenue
Portland, Oregon 97218

T.M. Davis
Harold W. Ager, Jr.
Ager & Davis Refining Company
9901 NE 33rd St.
Portland, Oregon

## PENNSYLVANIA

Lester Schurr
Berks Associates, Inc.
Box 305
Douglasville, Pa. 19518

## TENNESSEE

William M. Gurley
Gurley Oil Company
Box 2326
Memphis, Tennessee 38102

## TEXAS

R.A. Swasey
S & R Oil Company
Box 35516
Houston, Texas 77035

Abel Theriot
Capital Supply & Refining Company
Box 597
Hurst, Texas 76053

Texas American Oil
William F. Judd, President
Dallas, Texas

## UTAH

J.R. Mastelotto
Alco Refining Company
133 North First West
Salt Lake City, Utah 84113

## WASHINGTON

Superior Refineries, Inc.
Warren L. Bennett, President
Box 68
Woodinville, Wash. 98072

## WISCONSIN

M.A. Warden
Warden Refining Company
1910 South 73rd
W. Allis, Wisconsin 53214

## CANADA

J. Kalmacoff
Hub Oil Company Ltd.
5805 - 17th Avenue SE
Calgary 23, Alberta, Canada

Northern Oil Company
Stan S. Abracen
230 Norman St.
Ville St. Pierre, Quebec, Canada

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